URBAN BEST MANAGEMENT PRACTICES FOR NONPOINT SOURCE POLLUTION

Produced by the
Point and Nonpoint Source Programs
Water Quality Division
Wyoming Department of Environmental Quality

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PURPOSE

This "Best Management Practices" document is designed to provide a series of conservation practices. This document can be used as a guide for municipalities, private individuals and industries who are conducting day to day management activities in urban or suburban situations. When selected and applied properly, these urban best management practices (BMPs) will result in maintaining the existing beneficial uses of water resources and reducing adverse effects and water quality degradation. It is also being prepared as part of the "Wyoming Nonpoint Source Management Plan" as required by section 319(b) of the Clean Water Act.

Not all urban BMPs can remove both particulate and soluble pollutants. The choice of a particular BMP or series of BMPs depends on many factors. The quantity of storm water, types of pollutants expected, site location (residential, commercial, industrial), site topography, land costs, installation costs, and maintenance requirements will all affect BMP selection.

Several fundamental uncertainties still exist with respect to urban BMPs, including toxicity of residuals trapped by the practice; the interaction of groundwater with BMPs, and the long-term BMP performance.

This report is a compilation of information on several structural and non-structural BMPs. Specific BMPs may or may not be appropriate for a particular site or situation. Some of the BMPs discussed in this text may require design and construction oversight by a professional engineer. Permits may also be required from local, state or federal government for some types of BMPs. Be certain to check with appropriate agencies during the planning process to determine permit requirements. Thorough research, planning, and design should go into the selection and installation of any storm water BMP.

ACKNOWLEDGMENTS

A large part of this document is adapted from a publication from the Metropolitan Washington Council of Governments; *A Current Assessment of Urban Best Management Practices: Techniques for Reducing Nonpoint Source Pollution in the Coastal Zone* (Schueler, T.R., et al., 1992, 127 pp.).

The section on Miscellaneous BMPs for Urban Construction (BMP #18) is based, in large part, on a recent publication from the Denver Regional Council of Governments (DRCOG); *Keeping Soil on Site: Construction Best Management Practices* (1998, 76 pp.). The Nonpoint Source Task Force found this publication very helpful and relevant to conditions in Wyoming.

INTRODUCTION

Nonpoint source pollution (NPS) is generally considered to be a diffuse source of pollution not associated with a specific point of entry into the water body. Point sources are defined as any discernible, confined, and discrete conveyance from which pollutants are or may be discharged. Urban runoff is unique, in that most of the sources are the result of nonpoint influences. However, the conveyances to the surface waters are generally point sources.

Nonpoint sources of pollution include sediment from small construction sites, metals and other contaminants washed from streets and/or fertilizers or pesticides washing from lawns. The runoff becomes a point source because storm sewers, which are not connected to wastewater treatment plants, collect the runoff and convey it to surface waters.

Urban centers in Wyoming are typically located near surface water. In most cases, there are one or more streams flowing through our cities. Protecting these streams is a major challenge and becomes more critical as cities experience population increases.

Table 1 lists pollutants typically found in urban runoff. Runoff constituents specific to highways are listed in Table 2. Considerable effort has gone into identifying constituents in urban runoff, which can degrade the quality of surface and ground water. Agencies from several areas of the country have put significant time and resources into identifying the pathways by which these pollutants enter surface or ground water. For information on urban runoff in semi-arid environments, data from recent runoff studies in the Denver Metropolitan area have been included in Table 3.

Urban pollution presents some difficult problems. Pollutants accumulate during the time between rainfall events or before snowbelt. When rain falls or snow melts in the urban environment there is a sudden introduction of pollutants into lakes, rivers, wetlands, and groundwater; commonly known as the first flush effect.

The Wyoming Water Quality Division (WQD) Watershed Management Nonpoint Source Program is committed to working with local governments to assist in identifying water quality problems and implementing workable, cost effective solutions. To achieve this end, the Wyoming Nonpoint Source Task Force has compiled documentation on the following BMPs. For further information, a list of references is also included at the end of this document. In addition to government and academic sources, much information can be obtained on the internet. Some web sites are included in the reference section and more are available on the World Wide Web.

These practices are grouped under broad Categories which address a particular group of potential pollutant sources. Each Category reflects the greatest degree of pollutant reduction achievable through the application of a series of best management practices. The BMPs reflect the best control practices, technologies, processes, and operating methods available to address nonpoint source pollution problems in our cities.

Much of the research on urban BMPs has occurred on the east and west coasts in climate conditions that may not be applicable to Wyoming. However, Wyoming has a great diversity of local climates and each of these BMPs should be effective in at least some areas of the state. When evaluating a specific BMP consideration should be given to climate, as well as location, flow, expected pollutants, and maintenance requirements. Installing more than one practice in "series" may overcome the drawbacks of any single method, while providing enhanced pollutant removal.

One BMP that is critical to improving urban storm water quality is public education. Many urban residents are not aware that storm sewers do not carry runoff to treatment plants, but rather directly to nearby rivers. Residents should also understand that while the actions of a single person may seem insignificant, when combined with similar actions of hundreds or thousands of other residents, the potential to pollute their local waters is very real. The quart of oil dumped down a storm drain by one person on a given Saturday may be repeated hundreds of times that day.

Local development plans, ordinances and regulations may also play a role. Plans or regulations may encourage or mandate set backs from water bodies, treatment of runoff from construction sites or impervious areas, or percent allowable impervious area on a given lot size. Zoning requirements may be modified, if necessary, to allow residential development styles that reduce impervious areas and increase green space.

Existing Storm Water Regulations

In 1987 the United States Congress amended the federal Clean Water Act to include the regulation of some sources of storm water. The US Environmental Protection Agency (EPA) published regulations governing storm water discharges in 1990. In 1991, EPA granted the Wyoming Department of Environmental Quality (DEQ) primacy for the storm water program in Wyoming. DEQ primarily administers the program through two general permits, one for specific types of industrial activities defined in the federal regulations and the other for construction projects that clear or grade five or more acres. Under federal regulations storm water from covered sources is generally considered a "point source" whether or not it enters a storm sewer.

At this time, Wyoming has no municipalities required to obtain a storm water permit. Under existing regulations only those cities with a population of 100,000 or more are covered. Revisions to the storm water regulations, known as Storm Water Phase II, will include "urbanized areas" with populations of 50,000 or more. The urbanized areas will include Casper and Cheyenne **and** their surrounding developed areas in the county and nearby by towns such as Mills and Evansville near Casper. DEQ will also be required to evaluate cities with populations between 10,000 and 50,000 (Evanston, Gillette, Green River, Laramie, Rock Springs, Sheridan and their surrounding developed areas) for possible inclusion in the storm water permit program. A change for all Wyoming municipalities is the end of the municipal exemption for city or town owned industrial facilities such as maintenance garages. The incorporation of BMPs into the urban/suburban setting will become increasingly important as the changes associated with Storm Water Phase II begin to affect municipalities in Wyoming.

The precise requirements for municipal permits under the new regulations are not know at this time. The Storm Water Phase II regulations are expected to be published in 1999 and should begin to be implemented about three years later.

The size of construction projects covered under storm water regulations is also expected to decrease from a five acre minimum to one acre. Many urban/suburban construction projects that are not now required to obtain coverage will fall under the revised storm water regulations. These changes are expected to take effect about three years after final rule publication which should be in 2002.

Table 1 - Pollutants Typically Found in Urban Runoff *

COMMON URBAN RUNOFF POLLUTANT	SOURCE	AVERAGE CONCENTRATE	NONPOINT SOURCE IMPACTS
Sediment	Urban/ Suburban	80 mg/l Average	Fills in ponds and reservoirs with mud; contributes to decline of submergent aquatic vegetation by increasing turbidity and reducing the light available for photosynthesis, and covers or reduces spawning beds.. Acts as a sink for nutrients and toxicants and as a source when disturbed and resuspended.
Total Phosphorus	Urban/ Suburban	1.08 mg/l 0.26 mg/l	A contributing factor cited in eutrophication (nutrient over-enrichment) in receiving water bodies and subsequent algal blooms. Algal blooms contribute to the decline of submerged aquatic vegetation by reducing light available for photosynthesis, further degrade water quality by decreasing the level of dissolved oxygen (DO), increase Biological Oxygen Demand (BOD), and may cause changes in the composition of plankton and fish species.
Total Nitrogen	Urban/ Suburban	13.6 mg/l 2.00 mg/l	Like total phosphorus, contributes to eutrophication and algal blooms, though more typically in salt water bodies.
Chemical Oxygen Demand(COD)	Urban/ Suburban	163.0 mg/l 35.6 mg/l	Decreases the concentration of dissolved oxygen (DO). Low DO concentration and anaerobic conditions (complete absence of DO) can lead to fish kills and unpleasant odors. Primarily released as organic matter in the "first flush" of urban runoff after storm.
Bacteria	Urban/ Suburban	Avg.-200 to 240,000 MPN/L	High concentrations can lead to aquifer contamination and closure of shellfish harvesting areas and prevent swimming, boating, or other recreational activities.
Zinc	Urban/ Suburban	0.397 mg/l 0.037 mg/l	Chronically exceeds EPA water quality criteria. Many fish species highly sensitive to zinc. Primary cultural source is the weathering and abrasion of galvanized iron and steel.
Copper	Urban/ Suburban	0.105 mg/l 0.047 mg/l (Nationwide Avg.)	Chronically exceeds EPA water quality criteria. Primary cultural source is as a component of anti-fouling paint for boat hulls and in urban runoff, from the leaching and abrasion of copper pipes and brass fittings. An important trace nutrient, it can bioaccumulate, and thereby, create toxic health hazards within the food chain and increase long term ecosystem stress.
Lead	Urban/ Suburban	0.389 mg/l 0.018 mg/l	Lead from gasoline burning in automobiles is less of a problem today because of unleaded gasoline use. However, lead from scraping and painting bridges and overpasses remains. Chronically exceeds EPA water quality criteria. Attaches readily to fine particles that can be bioaccumulated by bacteria and benthic organisms while feeding. Lead has adverse health impacts when consumed by humans.
Oil and Grease	Urban/ Suburban	Avg. 2-10 mg/l	Toxicity contributes to the decline of zooplankton and benthic organisms. Accumulates in the tissues of benthic organisms; a threat to humans when consumed directly or when passed through the food chain. Primary cultural source is automobile oil and lubricants.
Arsenic	Urban/ Suburban	Avg. 6.0 Fg/l	An essential trace nutrient. Can be bioaccumulated; creates toxic health hazards within the food chain and increases long term stress for the ecosystem. Accumulates within tidal, freshwater areas, increasing the toxicity for spawning and juvenile fish. Primary cultural source is fossil fuel combustion.
Cadmium	Urban/ Suburban	Avg. 1.0 Fg/l	Primary cultural source is metal electroplating and pigments in paint. Can be bioaccumulated; creates toxic health hazards within the food chain and increases long-term toxic stress for the ecosystem.
Chromium	Urban/ Suburban	Avg. 5.0Fg/l	Primary cultural source is metal electroplating and pigments in paint. Can be bioaccumulated; creates toxic health hazards within the food chain and increases long-term toxic stress for the ecosystem.
Pesticides	Urban/ Suburban	Avg. <0.1 Fg/l	Primary urban source is runoff from home gardens and lawns. Can bioaccumulate in organisms and create toxic health hazards within the food chain. Also has been found as a contaminant in aquifers.

***Based on mid-Atlantic Coast data. Source: Metropolitan Washington Council of Governments, 1993 (as described in Terrene Institute, 1994).

Table 2
Highway Runoff Constituents and Their Primary Sources

Constituents	Primary Sources
Particulates	Pavement wear, vehicles, atmosphere, maintenance
Nitrogen, Phosphorus	Atmosphere, roadside fertilizer application
Lead	Leaded gasoline (auto exhaust), tire wear (lead oxide filler material, lubricating oil and grease, bearing wear)
Zinc	Tire wear (filler material), motor oil (stabilizing additive), grease
Iron	Auto body rust, steel highway structures (guard rails, bridges, etc.), moving engine parts
Copper	Metal plating, bearing and brush wear, moving engine parts, brake lining wear, fungicides and insecticides
Cadmium	Tire wear (filler material), insecticide application
Chromium	Metal plating, moving engine parts, brake lining wear
Nickel	Diesel fuel and gasoline (exhaust), lubricating oil, metal plating, bushing wear, brake lining wear, asphalt paving
Manganese	Moving engine parts
Cyanide	Anti-cake compounds (ferric ferrocyanide, sodium ferrocyanide, yellow prussiate of soda) used to keep deicing salt granular
Sodium, Calcium, Chloride	Deicing salts
Sulphate	Roadway beds, fuel, deicing salts
Petroleum	Spills, leaks or blow-by of motor lubricants, antifreeze and hydraulic fluids, asphalt surface leachate

Table 3
Storm Water Runoff Constituents, Denver Metropolitan Area and National Data

Parameter	Denver Metro-Industrial EMC*	Denver Metro-Commercial EMC*	Denver Metro-Residential EMC*	NURP - Median for Urban Sites
Total Phosphorus	0.43 mg/l	0.34 mg/l	0.87 mg/l	0.33 mg/l
Total Nitrogen	2.7 mg/l	3.9 mg/l	4.7 mg/l	2.2 mg/l
Chemical Oxygen Demand (COD)	232 mg/l	173 mg/l	95 mg/l	65 mg/l
Total Zinc	0.520 mg/l	0.294 mg/l	0.182 mg/l	0.160 mg/l
Total Copper	0.084 mg/l	0.081 mg/l	0.031 mg/l	0.034 mg/l
Total Lead	0.128 mg/l	0.059 mg/l	0.053 mg/l	0.144 mg/l

Data from Nationwide Urban Runoff Program (NURP) conducted 1978-1982 and from urban runoff monitoring conducted by Denver, Lakewood, and Aurora, CO in the early 1990s.
*EMC = Even Mean Concentration

URBAN BMP LIST

(Direct control practices and indirect prevention practices)

The following is a list of the practices included in this manual. Direct management practices are usually structural practices installed for the purposed of treating contaminated storm water. Indirect management practices are often non-structural methods that focus on pollutant reduction at the source or the use of existing natural features, such as vegetation, to reduce pollutants in storm water runoff.

Most practices work best with a specific type of pollutant, for example sediments or dissolved metals. When considering a practice or group of practices for a site the decision on what practices to adopt will depend on many factors including the pollutants to be removed, the cost of the practice, site location and size. The following pages address some common scenarios and list the BMPs that may be most appropriate to that activity.

<u>Direct Management Practices</u>

1. *Extended Detention Ponds*
2. *Wet Ponds*
3. *Storm Water Wetlands*
4. *Multiple Pond Systems*
5. *Infiltration Trenches*
6. *Infiltration Basins*
7. *Porous Pavement*
8. *Concrete Grid Pavement*
9. *Sand Filters*
10. *Grassed Swales*
11. *Filter Strips*
12. *Sediment Traps*
13. *Wind Erosion Controls*
14. *Check Dams - Filter Fence*
15. *Steep Slope Terraces*
16. *Water Quality Inlets/Oil Grit Separator*
17. *Streambank Stabilization - Structural w/ Vegetation*
18. *Miscellaneous BMPs for Urban Construction*

<u>Indirect Management Practices (Reduction/Prevention)</u>

19. *Direct Runoff Away From Natural Channels*
20. *Proper Disposal of Accumulated Sediment*
21. *Proper Snow Removal and Storage*
22. *Herbicide/Pesticide/Fertilizer Management*
23. *Protect Natural Vegetation and Riparian Vegetation*
24. *Recycling*
25. *Litter Removal*
26. *Street Sweeping*
27. *Exposure Reduction*

Locating detention ponds, infiltration basins, infiltration trenches, sand filters, and storm water injection wells within a wellhead protection area is discouraged. Snow storage and sediment disposal are also discouraged in wellhead protection areas.

RUNOFF FROM CONSTRUCTION SITES

INTRODUCTION

Construction contributes pollutants in a number of ways but it primarily increases sediment in surface waters. Vegetation removal on site exposes soils to the elements increasing erosion. Fuel, oil, and other lubricants from equipment, can contaminate ground water as well as surface waters if carried in runoff. Additional information on the problems with pollutant sources of associated with construction can be found in Appendix A.

CONDITIONS

- Residential homesite construction
- Commercial building construction
- Industrial complex construction
- Any type of construction in an urban area
- Recreation facilities
- Parking lot construction

PRACTICES

Direct Management Practices

11. *Filter Strips*
12. *Sediment Traps*
13. *Wind Erosion Controls*
14. *Check Dams - Silt Fence*
15. *Steep Slope Terraces*
17. *Streambank Stabilization - Structural and Vegetative*
18. *Miscellaneous BMPs for Urban Construction*

Indirect Management Practices (Reduction/Prevention)

19. *Direct Runoff Away From Natural Channels*
20. *Proper Disposal of Accumulated Sediment*
21. *Proper Snow Removal and Storage*
22. *Herbicide/pesticide/fertilizer Management*
23. *Protect Natural Vegetation and Riparian Vegetation*
24. *Recycling*
25. *Litter Removal*
27. *Exposure Reduction*

RUNOFF FROM EXISTING DEVELOPMENT

INTRODUCTION

In natural conditions, a high percentage of rainfall infiltrates into the ground. In urban settings, there is a higher percentage of impervious material resulting in a lower rate of infiltration. Impervious materials, such as pavement, rapidly channel runoff to a storm sewer conveyance. Storm sewers normally discharge directly into surface waters. Runoff entering these waters is normally untreated and carries a heavy pollutant load. Sediments, oils, fertilizers, and metals are the primary pollutants.

CONDITIONS

- Residential Neighborhoods
- Office Complexes
- Airports
- Commercial Districts
- Driveways and Sidewalks
- Rooftops
- Parking Lots and Structures
- Industrial Complexes

PRACTICES

Direct Management Practices

1. *Extended Detention Ponds*
5. *Infiltration Trenches*
6. *Infiltration Basins*
7. *Porous Pavement*
8. *Concrete Grid Pavement*
9. *Sand Filters*
10. *Grassed Swales*
11. *Filter Strips*
12. *Sediment Traps*
13. *Wind Erosion Controls*
14. *Check Dams - Filter Fence*
15. *Steep Slope Terraces*
16. *Water Quality Inlets/Oil Grit Separator*
17. *Streambank Stabilization - Structural and Vegetative*

Indirect Management Practices (Reduction/Prevention)

19. *Direct Runoff Away From Natural Channels*
20. *Proper Disposal of Accumulated Sediment*
21. *Proper Snow Removal and Storage*
22. *Herbicide/Pesticide/Fertilizer Management*
23. *Protect Natural Vegetation and Riparian Vegetation*
24. *Recycling*
25. *Litter Removal*
26. *Street Sweeping*
27. *Exposure Reduction*

RUNOFF FROM DEVELOPING AREAS

INTRODUCTION

These are areas that have the potential for increased development in the immediate future. In these situations there is the potential to consider problems, sources of pollution, and future needs. This allows urban planners to incorporate solutions before and during development. As one moves towards the fringes of urban areas, there may be state or municipal regulations to mitigate potential pollution to surface and ground water. An example is the introduction of green space to protect surface water riparian areas. Incorporating pollution prevention into development plans is generally simpler and more cost-effective than attempting to retrofit BMPs into existing sites.

CONDITIONS

- Subdivision Developments
- Office Park Development
- Mall Construction
- Gas Stations
- Recreation Facilities

PRACTICES

Direct Management Practices

1. *Extended Detention Ponds*
2. *Wet ponds*
3. *Storm water Wetlands*
4. *Multiple Pond Systems*
6. *Infiltration Basins*
7. *Porous Pavement*
8. *Concrete Grid Pavement*
9. *Sand Filters*
10. *Grassed Swales*
11. *Filter Strips*
12. *Sediment Traps*
13. *Wind Erosion Controls*
14. *Check Dams - Filter Fence*
15. *Steep Slope Terraces*
17. *Streambank Stabilization - Structural and Vegetative*
18. *Miscellaneous BMPs for Urban Construction*

Indirect Management Practices (Reduction/Prevention)

19. *Direct Runoff Away From Natural Channels*
20. *Proper Disposal of Accumulated Sediment*
21. *Proper Snow Removal and Storage*
22. *Herbicide/Pesticide/Fertilizer Management*
23. *Protect Natural Vegetation and Riparian Vegetation*
24. *Recycling*
25. *Litter Removal*
27. *Exposure Reduction*

GENERAL SOURCES (HOUSEHOLD, COMMERCIAL, AND LANDSCAPING)

INTRODUCTION

Each household in itself may not be a problem, but the combined cumulative effect of cleaning products, pesticides and fertilizers can be a significant pollution problem. Contamination may result from such practices as improper waste disposal or improper application of fertilizers. This can lead to eutrophication or over nitrification of streams, lakes and wetlands. The streams receiving contaminated storm water may double as a drinking water source.

CONDITIONS

- Residential Landscaping
- Office and Business Activities
- Commercial Landscapers
- Storage Buildings
- Auto Services
- Golf Courses
- Household Product Use and Disposal

PRACTICES

Direct Management Practices

2. *Wet ponds*
3. *Storm water Wetlands*
4. *Multiple Pond Systems*
5. *Infiltration Trenches*
7. *Porous Pavement*
8. *Concrete Grid Pavement*
9. *Sand Filters*
10. *Grassed Swales*
11. *Filter Strips*
13. *Wind Erosion Controls*
15. *Steep Slope Terraces*
17. *Streambank Stabilization - Structural and Vegetative*

Indirect Management Practices (Reduction/Prevention)

19. *Direct Runoff Away From Natural Channels*
21. *Proper Snow Removal and Storage*
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23. *Protect Natural Vegetation and Riparian Vegetation*
24. *Recycling*
25. *Litter Removal*
27. *Exposure Reduction*

ROADS, HIGHWAYS, AND BRIDGES

INTRODUCTION

Roads provide a direct path for conveying pollutants into storm sewers, and eventually surface waters. Roads collect pollutants while bridges often provide a direct route for pollutants to surface waters. Reconstruction and maintenance practices can increase pollutant loading.

CONDITIONS

- Reconstruction
- Placements
- Construction of Bridges
- Storm Sewer
- Major Repairs and Maintenance
- Addition of Gutters

PRACTICES

Direct Management Practices

1. *Extended Detention Ponds*
2. *Wet ponds*
3. *Storm water Wetlands*
5. *Infiltration Trenches*
6. *Infiltration Basins*
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11. *Filter Strips*
12. *Sediment Traps*
13. *Wind Erosion Controls*
14. *Check Dams - Filter Fence*
15. *Steep Slope Terraces*
16. *Water Quality Inlets/Oil Grit Separator*
17. *Streambank Stabilization - Structural and Vegetative*
18. *Miscellaneous BMPs for Urban Construction*

Indirect Management Practices (Reduction/Prevention)

19. *Direct Runoff Away From Natural Channels*
20. *Proper Disposal of Accumulated Sediment*
21. *Proper Snow Removal and Storage*
22. *Herbicide/Pesticide/Fertilizer Management*
23. *Protect Natural Vegetation and Riparian Vegetation*
25. *Litter Removal*
26. *Street Sweeping*
27. *Exposure Reduction*

WATERSHED PROTECTION

INTRODUCTION

Protecting urban watersheds includes maintaining a natural stream channel and floodplain. Use of green belts to maintain riparian areas creates buffer areas. Natural riparian areas provide storage for flood waters and established vegetation reduces bank erosion. Erosion and sediment controls reduce stream bed loads, improving water quality.

CONDITIONS

- New Subdivision
- New Development
- Urban Streambank Restoration
- Areas adjacent to Streams

PRACTICES

Direct Management Practices

1. *Extended Detention Ponds*
2. *Wet Ponds*
3. *Storm water Wetlands*
4. *Multiple Pond Systems*
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FACT SHEETS FOR URBAN BEST MANAGEMENT PRACTICES

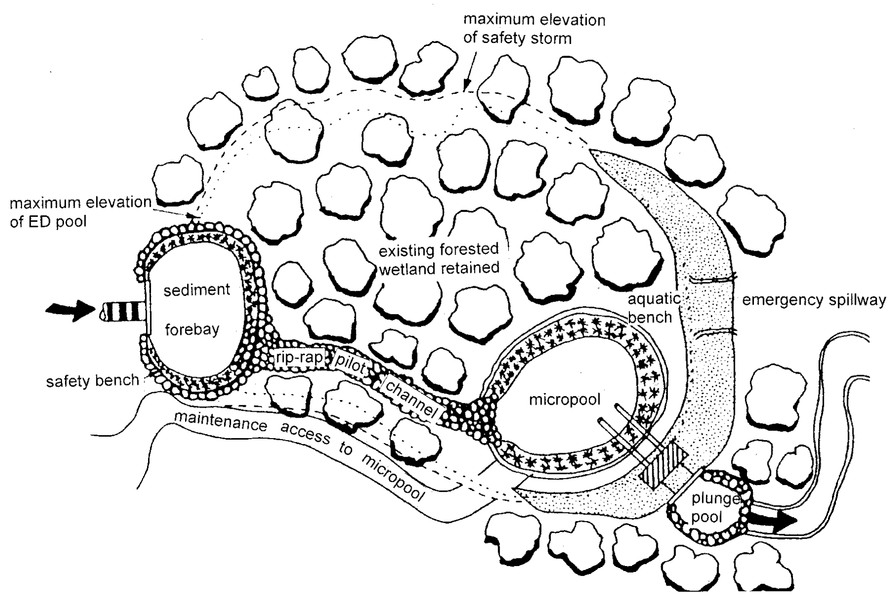
DIRECT MANAGEMENT PRACTICES

Definition

Conventional Extended Detention (ED) Ponds temporarily detain a portion of storm water runoff for up to twenty-four hours after a storm using a fixed orifice. Such extended detention allows urban pollutants to settle out. The ED ponds are normally dry between storm events and do not have any permanent standing water.

Enhanced ED Ponds are designed to prevent clogging and resuspension. They provide greater flexibility in achieving target detention times. Along with a detention area, they include a sediment forebay near the inlet, a micropool and/or plunge pool at the outlet, and utilize an adjustable reverse-sloped pipe as the ED control device to prevent resuspension of particles deposited in earlier storms.

Schematic Design of an Enhanced Dry ED Pond System



Source: Schueler, 1991.

Pollutant Removal Capability:

Conventional ED ponds provide moderate but variable removal of particulate pollutants, such as sediment, phosphorus and organic carbon, but provide negligible removal of soluble pollutants. Increasing detention times may result in greater removal of soluble pollutants.

Pollutant Removal Mechanisms: Pollutant removal is primarily accomplished by gravitational settling that is dependent on the detention time and the fraction of the annual runoff volume that is effectively detained in the pond (Schueler, 1987).

Review of Monitoring Studies: Six performance monitoring studies have been conducted to date. Reported removal for total suspended solids (TSS) ranges from 30 - 70 %, but is variable for smaller runoff events. For Total P, removal generally ranges from 10 - 30 %. For soluble nutrients, removal capability is estimated as low or negative. For chemical oxygen demand (COD), the removal rate ranges from 15 - 40 %. No data is yet available on the effectiveness of enhanced dry ED ponds.

Factors Influencing Pollutant Removal:

Positive Factors

- Six to twelve hours of detention (minimum) (MWCOG, 1983)
- Smaller treatment volumes (e.g. 0.5 watershed inches) provide the best removal rates (Pope and Hess, 1988)
- Wetlands in lower stage of design can prevent resuspension and augment removal of sediments
- Use of a micro pool to protect the ED pond orifice (Schueler and Helfrich, 1988)

Negative Factors

- Re-suspension of previously deposited pollutants from the pilot channel of pond floor (2,5)
- Large treatment volumes: acceptable ED times cannot be achieved over the broad range of expected storms (Schueler, 1992)
- Difficulty in predicting ED hydraulics (GKY, 1989)

Feasibility:

Feasibility: The enhanced ED pond can be utilized in most low visibility development situations, as a retrofit practice, or in combination with wetlands or permanent pools. May not be appropriate in high visibility residential or commercial settings.

Adaptability: ED ponds are an adaptable BMP that can be applied to most, if not all, regions of the country.

Contributing Watershed Area: In most cases, ED ponds are not practical if the watershed area is less than ten acres (Schueler, 1987).

Depth to Bedrock: If bedrock is close to the surface, high excavation costs may make ED ponds infeasible.

Depth to Water Table: If the water table is within two feet of the bottom of the ED pond, it can create problems with standing water and also indicate potential wetland status. Ground water contamination may be a problem if the soils are sufficiently porous (e.g. sandy) to allow infiltration to a high water table and storm water runoff is expected to be contaminated.

Use in Ultra-urban (highly developed) Areas: Fairly limited due to space constraints.

Retrofit Capability: Frequently used for storm water retrofits, particularly within dry storm water management ponds and at culvert/channel intersections. Usually used in combination with a micropool, wetland or permanent pool. (9,10)

Storm Water Management Capability: Frequently used in combination with two-year storm event control. Multiple outlets may be incorporated into the design to improve flexibility over a wide range of storm sizes.

Maintenance:

Primary maintenance activities include mowing; unclogging of the ED control device; and sediment clean out in the lower stage. The ED pond has the highest routine maintenance burden of any storm water quality pond system, due to mowing and clogging problems.

Factors Influencing Longevity: While few conventional ED ponds built to date have totally failed, many do not operate as designed and are not achieving target detention times. Greater longevity and reduced clogging can be achieved by:

- Two-stage design, utilizing wetlands in the lower stage (consistent water source necessary to incorporate wetlands)
- Smaller ED treatment volumes (i.e., avoid two-year ED)
- Use of single orifices located within the permanent micropool
- Avoidance of concrete pilot channels
- Equipping the pond with a drain
- Adjustable ED gate valves to achieve target detention times

Potential Benefits/Concerns

Positive Impacts:

- Extended detention is the best technique available for reducing the frequency of bank full and subbank full flooding events, and thereby is very useful in protecting downstream channels from erosion (Schueler, 1987)

- ED ponds can create both terrestrial and aquatic wildlife habitat with appropriate pondscaping and vegetation management

- They are less hazardous than other storm water quality ponds with deeper permanent pools

Negative Impacts:

- ED ponds can contribute to downstream warming if pilot channels are not shaded (Galli, 1991)

- Improper site selection can create wetland, forest and habitat conflicts (Schueler, 1991)

- Poorly maintained ED ponds are not popular with adjacent residents (Adams, et. al., 1983)

- Adequate space must be available to construct the extended detention pond.

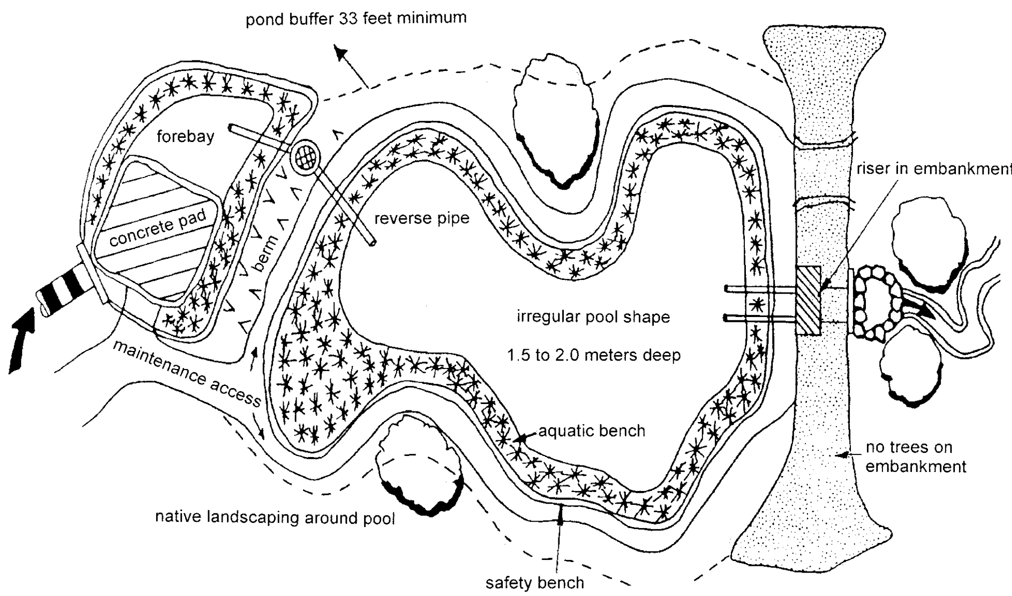
- May provide areas for insect nuisances such as mosquitos that will need control if the pond does not drain adequately between storm events.

Definition

Conventional Wet Ponds have a permanent water pool to treat incoming storm water runoff.

In **Enhanced Wet Pond** designs, a forebay is installed to trap incoming sediments where they can be easily removed; a fringe wetland is also established around the perimeter of the pond.

Schematic Design of an Enhanced Wet Pond System



Source: Schueler, 1991.

Pollutant Removal Capability:

Conventional wet ponds provide moderate to high removal of both particulate and soluble urban storm water pollutants. Reliable removal rates can be achieved with pool sizes ranging from 0.5 to 1.0 inches of runoff per impervious acre.

Pollutant Removal Mechanisms: Achieved by gravitational settling, algal settling, wetland plant uptake and bacterial decomposition (Driscoll, 1983). The degree of pollutant removal is a function of pool size in relation to contributing watershed area.

Review of Monitoring Studies: The pollutant removal capability of conventional wet ponds is well documented with over twenty performance monitoring studies in publication. Reported sediment removal typically ranges from 50-90%. Total phosphorus removal ranges from 30-90 %. Removal of soluble nutrients ranges from 40-80%. Moderate to high removals of trace metals, coliforms and organic matter are frequently reported.

Factors Influencing Pollutant Removal:

Positive Factors

- Pretreatment by sediment forebay (Livingston, 1989)
- Permanent pool, 0.5 - 1.0 inches per impervious acre treated (6,15)
- Fringe wetlands
- Shallow wetlands and/or extended detention may improve removal efficiencies (Adams, et. al., 1983)
- High length to width ratios

Negative Factors

- Small pool size (Driscoll, 1983)
- Fecal contribution from large waterfowl populations (Wu, et. al., 1988)
- Short-circuiting and turbulence (Martin, 1988)
- Sediment phosphorus release
- Extremely deep pool depths (greater than 10 feet)
- Snowmelt conditions and/or ice (Oberts, et. al., 1989)

Feasibility:

Feasibility: Wet ponds can be utilized in both low and high visibility development situations if contributing watershed area is greater than ten acres and/or a reliable source of baseflow exists.

Adaptability: Wet pond designs are not generally useful in arid regions where evapotranspiration significantly exceeds precipitation on an annual basis. Also, the size of the pool will need to reflect the prevailing climate and runoff frequency for a particular region. Ponds can be used in colder northern climates, but their performance declines slightly during ice and snowmelt runoff conditions. This practice may not be effective in more arid areas. Applications in Wyoming will need to be carefully chosen.

Contributing Watershed Area: Contributing watershed areas greater than ten acres and less than one square mile are generally suitable for wet ponds.

Baseflow: Dry-weather baseflow is needed to maintain pool elevations and prevent pool stagnation.

Available Space: Wet ponds and associated buffer/setbacks can consume from one to three percent of total site area.

Development Situations: Very useful in both low and high visibility commercial and residential development applications.

Use in Ultra-urban Areas: Use in ultra-urban areas is fairly limited due to space constraints, but can provide an attractive urban amenity if open space or parkland is available.

Retrofit Capability: Occasionally used for storm water retrofits, particularly within dry storm water basins (Schueler, et. al., 1991). Often used in combination with wetlands or extended detention treatment techniques.

Storm Water Management Capability: Most wet ponds can provide two-year storm water quantity control, in addition to quality control.

Maintenance:

Wet ponds have a modest maintenance burden, consisting primarily of inspections, mowing of the embankment and buffers, and removal of sediment, trash and debris from the forebay. All studies to date indicate that pond sediments meet sludge toxicity limits and can be safely land filled (23,53,54)

Factors Influencing Longevity: Well-designed wet ponds can function for twenty years or more and very few conventional ponds have ever failed to provide some water quality benefit. Performance will decline over time, however, unless regular sediment clean out is undertaken. Factors influencing the longevity of wet ponds include:

- Installation of a sediment forebay (Schueler, 1992)
- Regular (2 - 5 year) sediment clean-outs (Schueler and Helfrich, 1988)
- Reverse-slope pipes
- On-site sediment disposal area

- Use of concrete riser/barrels rather than corrugated metal pipe

Potential Benefits/Concerns:

Positive Impacts:

- Creation of wetland features
- Creation of aquatic and terrestrial habitat (particularly for waterfowl)
- Creation of a warm-water fishery
- High community acceptance and landscaping values (Adams, et. al., 1983)
- Pollutant removal and downstream channel protection

Negative Impacts:

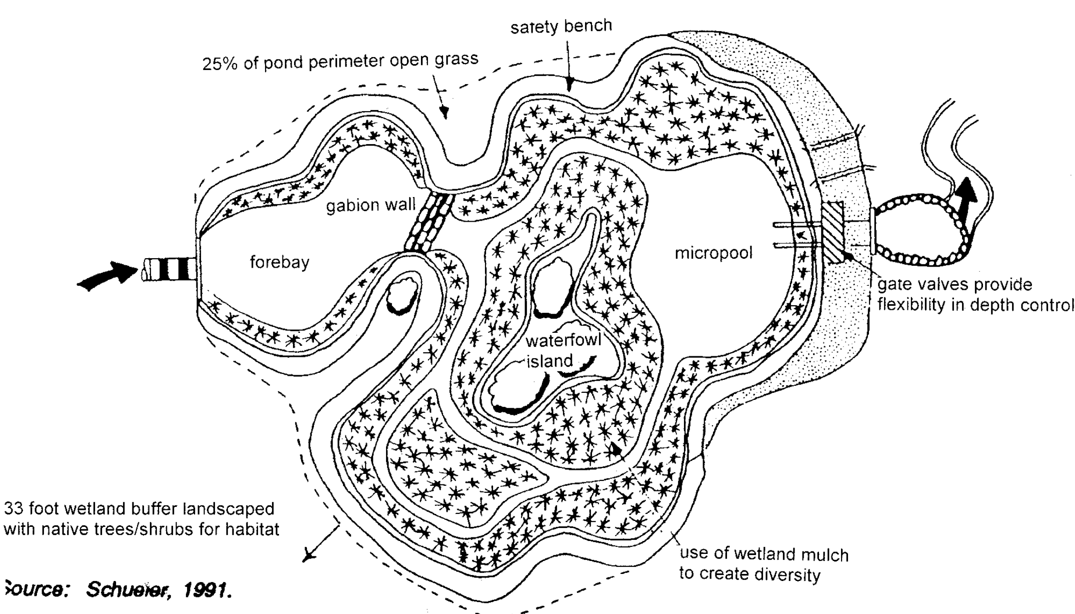
- Downstream warming (Galli, 1991). May not be appropriate on streams with cold water fisheries.
- Upstream channels may be impacted when wet ponds serve large drainage areas (> 250 acres) (Schueler, 1991)
- Potential loss of wetlands, forest and floodplain habitat associated with poor site selection for the pool (Schueler, 1991)
- Downstream shifts in trophic status (Galli, 1988)
- Limited risk of ground water quality impacts over the long term; all studies to date indicate that wet ponds do not significantly contribute to ground water contamination (USEPA, 1991)
- Potential hazard for nearby residents due to the presence of standing water. The inclusion of a shallow safety bench around the pond may reduce potential hazards. Additionally, growth of dense vegetation (cattails, willows, etc.) will limit access and hazards to residents.
- Provide areas for insect nuisances such as mosquitos that will need control

Definition

Conventional Storm Water Wetlands are shallow pools that create growing conditions suitable for the growth of marsh plants. These storm water wetlands are designed to maximize pollutant removal through wetland uptake, retention and settling. **Storm water wetlands** are constructed systems and typically are not located within delineated natural **wetlands.** In addition, storm water wetlands differ from other artificial wetlands created to comply with mitigation requirements in that they do not replicate all the ecological functions of natural wetlands. Functional differences will depend on the design of the storm water wetland, interactions with groundwater and surface water, and local storm climate.

Enhanced Storm Water Wetlands are designed for more effective pollutant removal and species diversity. They also include design elements such as a forebay, complex microtopography, and pondscaping with multiple species of wetland trees, shrubs and plants.

Schematic Design of an Enhanced Shallow Marsh System



Source: Schueler, 1991.

Pollutant Removal Capability:

In general, conventional storm water wetlands have a high pollutant removal capability that is generally comparable to that of conventional wet ponds. Sediment removal may be greater in well designed storm water wetlands, but phosphorus removal is more variable.

Pollutant Removal Mechanisms: Wetlands remove pollutants through gravitational settling, wetland plant uptake, adsorption, physical filtration and microbial decomposition. Primary removal of storm water pollutants occurs during the relatively long quiescent period between storms (Livingston, et. al., 1997). The degree of pollutant removal is a function of aquatic treatment volume, surface area to volume ratio, and the ratio of wetland surface area to watershed area (16, 26, 27). Additionally, longer storm water flow paths through the wetland and longer residence times within the wetland is expected to improve pollutant removal.

In western states wetland vegetation may be dormant during early spring snowmelt and rain events. However, since plant uptake is only one of several mechanisms in the removal of most pollutants, a standing crop of vegetation can still provide filtration and an area for surface removal processes (Livingston, et. al., 1997).

Review of Monitoring Studies: Eighteen studies of the performance of conventional natural and constructed wetlands are available. Removal rates are generally comparable to those reported for conventional wet ponds of similar treatment volume; however, sediment removal rates are often slightly higher and nutrient removal rates are somewhat lower. Some cases of negative removal for ammonia and ortho-phosphorus were reported. The addition of ammonia or ortho-phosphorous may be due, in part, to wildlife use and populations and vegetation management (Livingston, et. al., 1997). Overall performance is greatest during the growing season and lowest during the winter months (Strecker, et. al., 1990).

Factors Influencing Pollutant Removal:

Positive Factors

- Constant pool elevations (Schueler, 1992)
- Range of micro topography within the wetland (Schueler, 1992)
- Sediment forebay
- High surface area to volume ratio (Strecker, et. al., 1990)
- Constructed wetland performs better than natural wetland
- Adding greater retention volume and/or detention time to the wetland (26, 28)
- Effective in areas with high water table or poorly drained soils (Livingston, et. al., 1997)
- Lengthy travel paths for storm water

Negative Factors

- Lower removal rate during non-growing season (Athanas and Stevenson, 1991)
- Concentrated inflows (Strecker, et. al., 1990)
- Wetland area less than two percent of watershed area
- Sparse wetland cover (OWML and GMU, 1990)
- Ice cover or snowmelt runoff (Oberts, et. al., 1989)

Feasibility:

Feasibility: Enhanced storm water wetlands can be applied to most development situations where sufficient baseflow is available to maintain water elevations.

Adaptability: Enhanced storm water wetlands can be adapted for most regions of the country that are not excessively arid. Storm water wetlands may not be appropriate for all areas of Wyoming. A careful review of local climate and water table conditions should be conducted before choosing this BMP.

Contributing Watershed Area: Storm water wetlands can be used in watersheds as small as five acres. However, the installation of many small wetlands increase maintenance costs (Galli, 1992). “Pocket wetlands” (generally less than 0.1 acres) have been used successfully at culvert and parking lot outlets in Minnesota (Debo and Reese, 1995).

Presence of Baseflow: To maintain a constant water level, it is often necessary to have a reliable dry-weather baseflow to the wetland or a groundwater supply.

Permeable Soils: It is difficult to establish wetlands at sites with sandy soils, high soil infiltration rates or high summer evapotranspiration rates.

Available Space: Because of their shallow depths, storm water wetlands can consume two to three times the site area compared to other storm water quality options (in some cases, as much as five percent of total site area). The land requirements of storm water wetlands can be sharply reduced by deepening parts of the wetland, thus extending detention times. However, side slopes along the edge of the wetland must remain gradual to maintain emergent vegetation around the wetland.

Use in Ultra-urban Areas: Limited due to space constraints; however, pollutant removal can be obtained by modifying existing degraded urban wetlands for storm water control. Incorporating a shallow “safety bench” around the edge of a wetland or promoting dense vegetative growth around the perimeter to limit access, may mitigate some safety concerns in urban areas.

Retrofit Capability: The addition of wetland features to older dry storm water basins is an effective retrofit technique (Strecker, et. al., 1990). Many retrofits utilize a combination of extended detention, wetlands and a permanent pool.

Storm water Management Capability: In most cases, storm water detention can be provided in storm water wetlands.

Maintenance:

Well designed conventional storm water wetlands should function for many years. The inclusion of a forebay, or wet cell, that concentrates sediment deposition in an area where it can be easily removed without disturbing the entire system is an important part of the design.

Storm water wetlands may require greater maintenance in the first several years to establish the marsh. Thereafter, the maintenance burden is similar to other pond systems.

Factors Influencing Longevity:

- Sediment forebay to collect sediment before it enters the wetland
- Ability to regulate water depths
- Replacement plantings (Schueler, 1992)
- Selection of an experienced wetland contractor for design (RIDEM, 1989)
- Control of undesirable plant species such as purple loosestrife

Failure Rates: While most conventional storm water wetlands have persisted over time, the quality and coverage of wetland plants may not be optimal for pollutant removal. It should be noted that few storm water wetlands meet the strict success criteria for wetland mitigation, but they are not intended to do so.

Potential Benefits/Concerns:

Positive Impacts:

Storm water wetlands can provide an excellent urban habitat for wildlife and waterfowl, particularly if they are surrounded by a buffer and have some deeper water area (Athanas, 1986)

Negative Impacts:

Possible impact on wetland biota from trace metal uptake (Strecker, et. al., 1990)

Storm water wetlands may cause warming of downstream waters (Galli, 1991)

Construction may adversely impact existing wetland or forest areas (6, 30)

Possible takeover by invasive aquatic nuisance plants (e.g., loosestrife, cattails and phragmites) (Stockdale, 1991)

Bacterial contamination if waterfowl populations are dense (Wu, et. al., 1988)

If sediment is not properly settled out before the storm water enters the wetland, the wetland will likely become choked with sediment in a few years

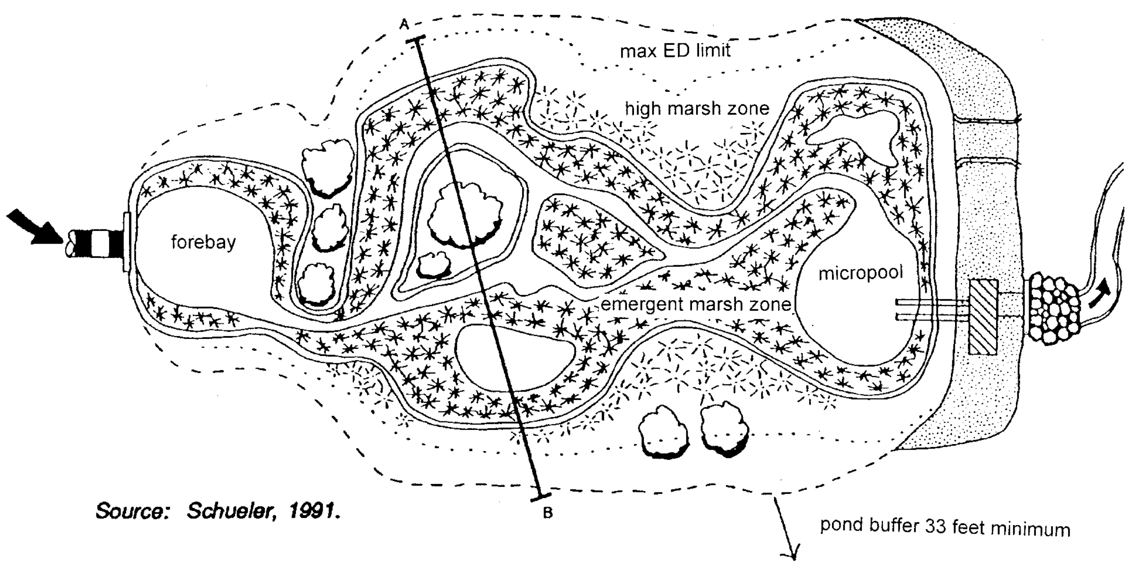
Provide areas for insect nuisances such as mosquitos that will need control

MULTIPLE POND SYSTEMS *BMP Fact Sheet #4*

Definition

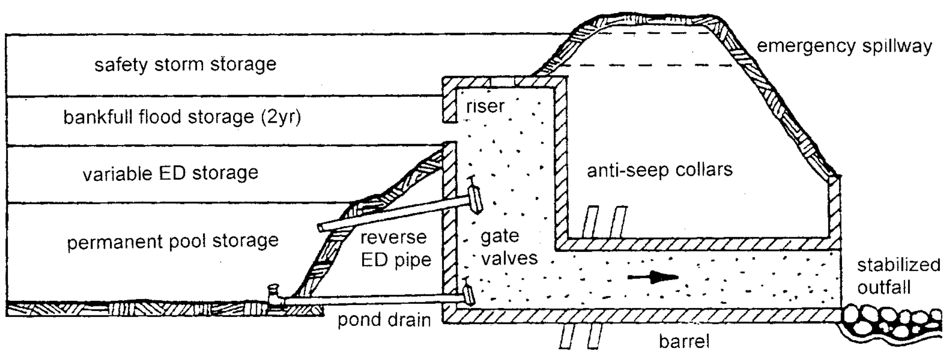
Multiple Pond Systems is a collective term for a cluster of pond designs that incorporate redundant runoff treatment techniques within a single pond or series of ponds. These Pond designs employ a combination of two or more of the following: extended detention, permanent pool, shallow wetlands, or infiltration in a "treatment train." Examples of a multiple pond system include the wet ED pond, ED wetlands, infiltration basins and pond-marsh systems.

Schematic Design of a Shallow ED Marsh System



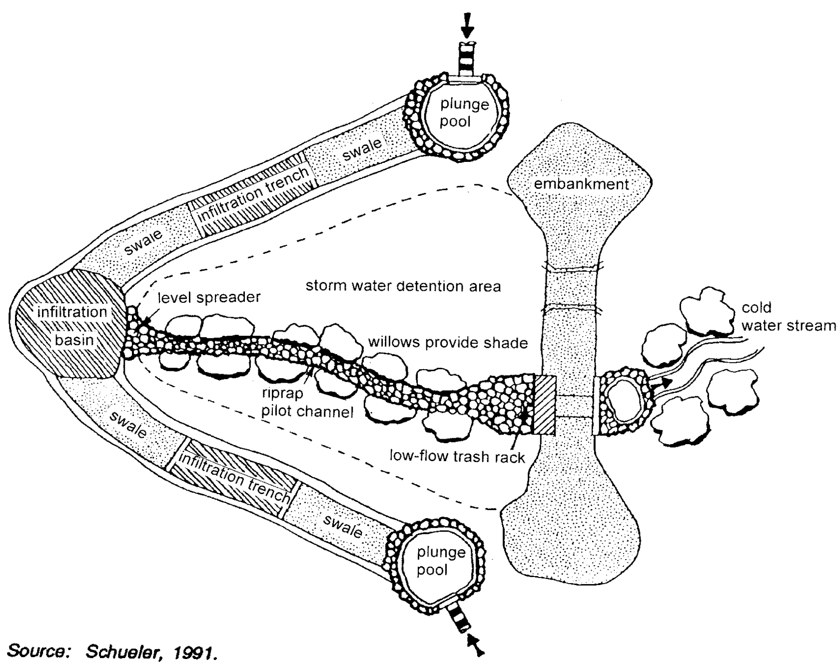
Source: Schueler, 1991.

Cross-section View of a Standard ED Pond System Design



Source: Schueler, 1991.

Schematic Design of a Dry In-filter System



Source: Schueler, 1991.

Multiple pond systems (MPS) have evolved as a common approach to provide storm water quality control over the past five years. MPS is a collective term for a wide variety of approaches to storm water pond design. While many aspects of their design are unique and site-specific, they do share several common features:

Redundancy: The MPS designs emphasize the use of multiple treatment mechanisms (such as a permanent pool, extended detention, wetlands, within a pond or series of ponds), rather than a single method of treatment. The use of treatment methods in series helps to improve both the level and reliability of pollutant removal provided by the pond system.

Flexibility: Because the location and allocation of treatment mechanisms is not rigid, the designer of an MPS has a great deal of flexibility in responding to site-specific conditions. Additionally, the flexibility enables the designer to minimize or avoid negative environmental impacts that can be created by single ponds.

Complexity: MPS are inherently more complex in design than single treatment ponds. Typically, MPS systems have more sophisticated hydrologic control devices that are targeted toward different patterns of the annual runoff frequency spectrum. In addition, some MPS have interconnected cells within a pond.

Pollutant Removal Capacity:

Many MPS are reported to provide incrementally higher and more consistent levels of urban pollutant removal in comparison to single treatment systems. This improvement is due to a number of factors:

Multiple-cell Ponds: Studies have shown that multiple cell ponds tend to have incrementally higher levels of pollutant removal when compared to single cell ponds (Horner, 1988). The superior performance of multiple cell ponds can be attributed to a longer flow path, possible reductions in short circuiting, and increases in retention time. Short circuiting occurs when inflow by passes “dead storage” areas where little or no mixing occurs. Multiple pond systems lengthen the path of storm water flow with respect to the width of the pond areas, reducing or avoiding short circuiting.

Wet Pond/Wetland Systems: MPS that utilize a wet pond cell leading to a wetland cell have been reported to be very effective in removing pollutants from urban runoff (19,28, 33, 34). The wet pond cell is apparently very effective in pre-treating the incoming runoff; it also reduces its velocity and distributes it more evenly across the marsh.

Extended Detention/Wetland Systems: Wetlands are believed to improve the effectiveness of conventional extended detention (ED) in several ways. The plants help stabilize deposited sediments, take up nutrients, and create more ideal settling conditions.

The extent of the improved pollutant removal attributable to ED-wetland systems is not well documented, however. Four performance studies of ED-wetland systems have been reported and these indicate moderate to high removal of particulate pollutants, and low to moderate removal of soluble pollutants. However, all four systems studied had inadequate treatment volumes to provide for optimum pollutant removal (0.08 to 0.15 inches of runoff per contributing acre).

Wet Extended Detention Ponds: The wet extended detention pond system has been projected to have higher and more reliable pollutant removal than a wet pond or an ED pond acting alone. This superior performance is due to the role of the pool in acting as a barrier to re-suspension and the role of ED in increasing retention times for the full range of storms (Schueler and Helfrich, 1988). Limited monitoring conducted to date supports this contention.

Feasibility:

MPS are generally subject to the same feasibility requirements associated with conventional pond systems.

Adaptability: MPS are adaptable for use in most regions of the country. In arid or extremely cold regions, more of the total storage in the MPS should be devoted to extended detention. In cold regions extended detention provides more volume for snowmelt and early spring rains. In arid areas maintaining large wetlands without a consistent water source may not be practical.

Maintenance:

MPS have a maintenance burden similar to that of conventional pond systems. While the MPS may have more complex operation (e.g., adjustment of valves), their design incorporates numerous features that can reduce routine and non-routine maintenance (e.g., mowing and sediment removal).

Longevity: The longevity of MPS is expected to be at least comparable to conventional pond systems. Often, one treatment storage component can be used to protect the long term capacity of another component. For example:

Wet Pond/Wetland Systems: The wet pond cell traps the majority of the incoming sediment, thereby preserving treatment capacity in the wetland and maintaining optimum water depths.

Dry Infilter Systems: The plunge pool, grassed swale and filter fabric provide excellent pretreatment of runoff before it enters the trench, thereby enhancing its longevity. A dry infilter pond has been operating with only minor clogging for over six years in Maryland.

All Multiple Pond Systems: The basic design of all MPS has two features that promote greater longevity for ponds. The first is the subsurface reverse-slope pipe used as the hydrological control device. This design feature greatly reduces clogging. The second design feature is the forebay, or wet cell, which concentrates sediment deposition in an area where it can be easily removed without disturbing the entire system.

Environmental Attributes:

The flexibility of MPS enables the designer to minimize or avoid many secondary impacts commonly associated with ponds. The ability to allocate treatment storage components, or locate them in series can aid the designer in customizing the MPS to avoid disruption to forests and wetlands. Similarly, by allocating less storage to the permanent pool (and more to ED), one can reduce the potential delta of the pond. In addition, by combining wetlands with conventional wet ponds or extended detention ponds, it is possible to significantly enhance the habitat value. Finally, by adding ED to wetlands or wet ponds, one can provide a greater degree of downstream channel protection. A comparison of some of the advantages and disadvantages of alternative pond designs are illustrated in Appendix A, Table 1.

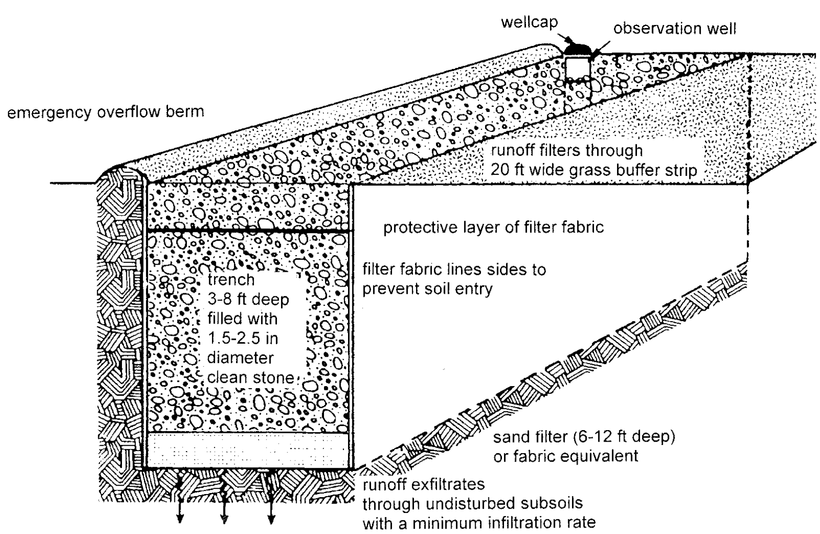
Definition

a Conventional Infiltration Trench is a shallow, excavated trench that has been backfilled with stone to create an underground reservoir. Storm water runoff diverted into the trench gradually exfiltrates from the bottom of the trench into the subsoil and eventually into the water table. Trenches may be designed to accept the "first flush" volume (½ runoff per acre of impervious surface) or for larger volumes of runoff. A design variation is a dry well to control small volumes of runoff, such as roof top runoff.

Enhanced Infiltration Trenches have extensive pretreatment systems to remove sediment and oil.

Both types of trenches require on-site geotechnical investigations to determine appropriate design and location.

Schematic Design of a Conventional Infiltration Trench



Source: Schueler, 1987.

Pollutant Removal Capability:

Although actual performance data on conventional infiltration trenches is rare, trenches are believed to have high capability to remove particulate pollutants and a moderate capability to remove soluble pollutants.

Pollutant Removal Mechanisms: Include adsorption, straining and microbial decomposition in the soil below the trench and trapping of particulate matter within pretreatment areas (i.e., grass filter strips, sump pits and plunge pools) (Schueler, 1987).

Review of Monitoring Studies: Very few studies monitoring the performance of conventional infiltration trenches have been conducted to date (Woodward-Clyde, 1991). Estimates of performance have been inferred from studies of rapid infiltration land wastewater treatment systems or by modeling (1, 21). For sediment removal, rates in excess of 90% are cited; for phosphorus and nitrogen removal, the rate is estimated at 60%. Removal rates for trace metals, coliforms and organic matter are estimated at 90%. Lower rates are expected for nitrate, chlorides and soluble trace metals, particularly in sandy soils (25, 35).

Factors Influencing Pollutant Removal:

Positive Factors

- Bank run or washed aggregate
- High organic matter and loam content of subsoil (Kuo, et. al., 1990)
- Capture of a large fraction of annual runoff volume
- Effective pretreatment system, e.g., a sump pit (Schueler, et. al., 1991)
- Pretreatment of sediments, oils, greases

Negative Factors

- Sandy soils
- Trench clogging
- High water table
- Long de-watering times (Galli, 1992)

Feasibility:

Feasibility: The application of trenches, like other infiltration practices, is severely restricted by soils, water table, slope and contributing area conditions. These conditions must be carefully investigated in the field before proceeding with design.

Adaptability: The widespread use of infiltration trenches may be limited in areas where the ground commonly freezes or more arid climates where wind erosion may introduce a significant sediment load. Infiltration trenches are also less effective in regions where soils are predominantly clays or silts.

Soils: Trenches are not practical in soils with field-verified infiltration rates of less than 0.5 inches per hour (particularly silty or clayey soils). Soil borings should be taken well below the proposed bottom of the trench to identify any restricting layers (MDE, 1983).

Area: Maximum contributing drainage area to an individual trench should not exceed five acres.

Slope: The effectiveness of surface trenches is sharply reduced if slopes are greater than five percent.

Depth to Bedrock and Depth to Water Table: Three feet of clearance from bottom of trench to the water table is recommended.

Ground Water: Trenches may not be easily adaptable in regions where ground water is used locally for human consumption or in areas where particularly hazardous pollutants may be present.

Sediment Inputs: Conventional trenches may not be advisable on sites expected to provide high levels of sediment input.

Climate: Trenches may not perform well in regions with long, cold winters and deep freeze-thaw levels. Trenches may not be appropriate in arid regions with sparse vegetative cover in upland areas that might contribute high sediment levels.

Use in Ultra-urban Areas: Very limited due to unsuitable soils. Soils in urban areas are often disturbed and compacted due to previous construction or landscaping.

Retrofit Capability: Very limited due to unsuitable soils (Galli and Herson, 1989).

Storm water Management Capability: Some trench designs can provide storm water quantity requirements; however, most trenches function only as water quality BMPS.

Maintenance:

To enhance longevity and maintain performance, trenches and associated pretreatment systems do require significant maintenance. Most conventional trenches do not appear to be regularly maintained in the field and thus many will require costly rehabilitation or replacement to maintain their function.

Longevity: Thus far, conventional trenches have proved to have short life spans. Slightly over half partially or totally fail within five years of construction. Longevity could be greatly improved through the utilization of enhanced trenches (i.e., runoff pretreatment, better geotechnical evaluation and regular maintenance).

An underdrain installed during construction of an infiltration trench may increase longevity by allowing conversion to a sand filter should the trench fail due to poor exfiltration. The drain would remain capped until the trench failed.

Factors Influencing Longevity: The relatively short life span of conventional trenches could be significantly increased by the following:

- Field verification of soil infiltration rates and water table location (Galli, 1992)
- Careful site selection to avoid areas with very high sediment loads.
- Use of pretreatment systems that provide some degree of storage (e.g. sump pits, swales with check dams, plunge pools) (Galli, 1992)
- A layer of filter fabric one foot below surface of trench (Schueler, 1987)
- Use of a sand layer rather than filter fabric at the bottom of a trench (Galli, 1992)
- Avoiding construction until all contributing watershed disturbances and construction activities are completed (MDE, 1983)
- Rototilling of trench bottom to preserve infiltration rates (Galli, 1992)

Failure Rates: According to data from Maryland (Metropolitan Washington Council of Governments), about one in five conventional trenches fails to operate as designed immediately after construction; further-more, barely half of all conventional infiltration trenches operated as designed after five years. (Many of these had become partially or totally clogged.) Based on these data, it would appear that conventional trenches have a design life-span of less than five years without adequate pretreatment.

A second study of infiltration trench longevity in Maryland indicated that approximately fifty-five percent of trenches are not operating as designed (Galli, 1992). According to the study, one-third of the trenches were partially or totally clogged; another twenty percent had significant inflow problems. The oldest trench surveyed was five years old.

Potential Benefits/Concerns:

Positive Impacts:

- Groundwater recharge
- Reduction in downstream bank full flooding events
- Some reduction of peak storm water discharge

Negative Impacts:

- Slight to moderate risk of groundwater contamination depending on soil conditions. Infiltration trenches or basins are not recommended in areas where the potential of significantly polluted surface runoff exists.

- No habitat is created

- High failure rates of conventional trenches sharply limit the ability to meet storm water and water quality goals at the watershed scale

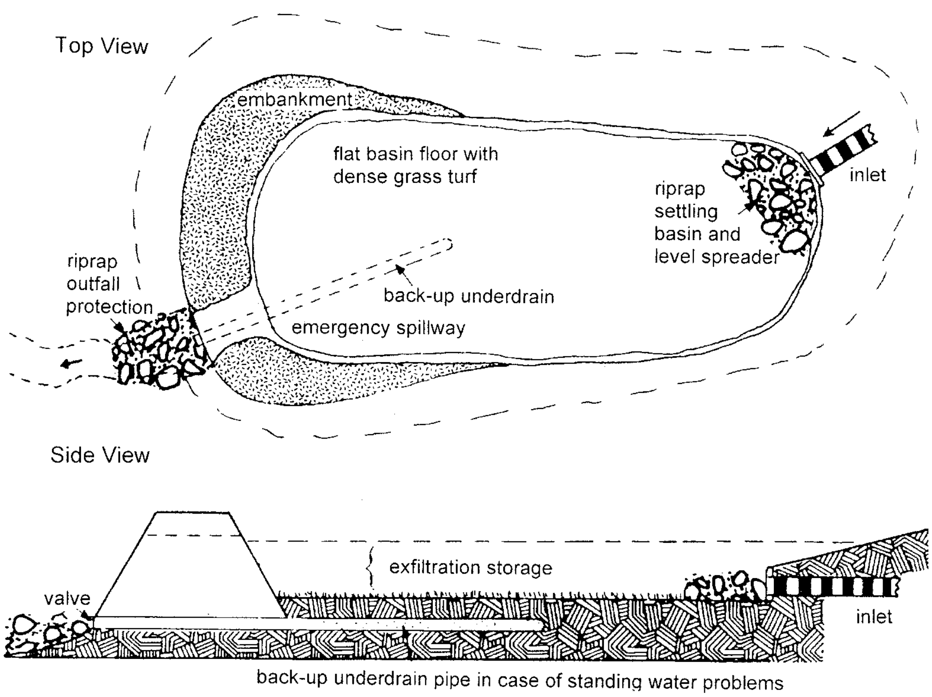
- May cause an increase in the groundwater table, resulting in flooding of structures with basements. This is more likely to be a problem in areas with existing high water table.

INFILTRATION BASINS *BMP Fact Sheet #6*

Definition

Infiltration basins are impoundments where incoming storm water runoff is stored until it gradually exfiltrates through the soil of the basin floor.

Schematic Design of an Infiltration Basin



Source: Schueler, 1987.

Pollutant Removal Capability:

No performance data on infiltration basins is available; however, they are presumed to have the same general removal efficiencies reported for infiltration trenches: high removal for particulate pollutants and moderate removal for soluble pollutants.

Pollutant Removal Mechanisms: As with other infiltration systems, removal is accomplished by adsorption, straining, and microbial decomposition in the basin subsoils as well as the trapping of particulate matter within pretreatment areas (Schueler, 1987). Drainage of the basin should occur within a minimum of 72 hours to maintain aerobic conditions and promote microbial removal of pollutants.

Review of Monitoring Studies: No actual performance data is available to evaluate the pollutant removal capability of infiltration basins (Woodward-Clyde, 1991). Estimates have been inferred from studies of rapid infiltration of land-applied wastewater effluent and from modeling studies (Schueler, 1987). Removal efficiencies are presumed to be high for particulate pollutants and moderate for soluble pollutants. Lower rates are expected for nitrate, chlorides and soluble trace metals, particularly in sandy soils (USEPA, 1991). Actual pollutant removal is projected to be related to the proportion of the annual runoff volume successfully exfiltrated into the subsoil.

Factors Influencing Pollutant Removal:

Positive Factors

- Forebay
- Short dewatering time
- Back-up underdrain systems
- Small contributing watershed
- Dense vegetative cover
- Non-concentrated flow
- Drainage within 24-72 hours

Negative Factors

- Basin clogging
- High water tables
- Clay and silt soils
- High sediment inputs
- Large contributing watershed area
- Long dewatering times
- Algal growth
- Large depth of standing water (Galli, 1992)

Feasibility:

Feasibility: The application of basins is restricted by numerous site factors (soils, slope, water table and contributing watershed area).

Adaptability: Infiltration basins may not be applicable in areas of cold winters, arid growing seasons or impermeable soils.

Soils: Basins are not feasible at sites with field-verified soil infiltration rates of less than 0.5 inches/hour. Soil borings should be taken well below the proposed bottom of the basin to identify any restricting layers (MDE, 1983).

Contributing Watershed Area: Normal contributing drainage area ranges from two to fifteen acres. Larger drainage areas are not generally recommended.

Depth to Bedrock/Seasonally High Water Table: Minimum of three feet.

Sole-Source Aquifers: Regions with sole-source aquifers may not be suitable.

Pretreatment: Basins are not recommended unless upland sediment inputs can be pretreated.

Land Use: Some caution should be exercised when applying a basin in a watershed with a risk of chronic oil spills or other hazardous materials.

Use in Ultra-urban areas: Not recommended.

Retrofit Capability: Not recommended (Schueler, et. al., 1991).

Storm water Management Capability: In some instances, a basin can provide storm water management detention, but it is not generally recommended.

Maintenance:

Regular maintenance activities apparently cannot prevent rapid clogging of infiltration basins. Once clogged, it has been very difficult to restore their original function; thus, many have been converted to retention basins or wetlands.

Longevity: Infiltration basins do not have long life spans. Sixty to one hundred percent of basins studied could no longer exfiltrate runoff after five years. Major design refinement and site investigation will be required to achieve sufficient longevity.

Installation of a back-up underdrain may extend the life of a basin by essentially converting it into a sand filter. The drain, normally capped, may be opened when exfiltration is no longer effective.

Failure Rates: The failure rates for infiltration basins in the mid-Atlantic region range from sixty to one hundred percent in the first five years, according to two recent studies (8, 36, 37). Up to fifty percent had failed shortly after construction. The primary reason for failure is clogging. Of twelve basins in Maryland, none were able to exfiltrate runoff after five years (Galli, 1992). These basins had an average standing water depth of one foot.

All these basins were partially covered by wetland vegetation and/or algal mats. The basins had become defacto retention ponds; some sixty percent were still providing partial water quality treatment. About twenty percent of infiltration basins studied in Maryland have been retrofitted into pond systems (MDE, 1991).

Factors Influencing Longevity: Clearly, current infiltration basin designs do not perform adequately. The following factors appear to contribute significantly to improved life-span for infiltration basins:

- Shorter dewatering rate (24 hours rather than 72 hours)
- Pretreatment forebays to control sediment inputs
- Small contributing watershed areas
- Shallow basin depths (standing water appears to promote soil compaction)
- Off-line designs that bypass large storms and sediment inputs
- More efficient dewatering mechanisms in basins (e.g., stone trenches rather than soil) (Bergling, 1991)
- Careful geotechnical investigation of soil conditions prior to excavation
- Use of sand as a surface layer in the basin
- Installation of underdrains into the basin

It is difficult to determine whether the design changes, as proposed above, would achieve sufficient longevity. Local communities should be cautious in promoting infiltration basins until:

- the longevity and performance of the new generation of infiltration basins is adequately demonstrated
- the basic infiltration basin design is readily convertible into a retention basin

Potential Benefits/Concerns:

Positive Impacts:

- Groundwater recharge helps to maintain dry-weather flows in streams
- Reduction in downstream bank full flooding events. Partial replication of pre-development hydrology.

  (Note: The short lifetimes of basins as currently designed suggest that the positive hydrological and water quality impacts may not be realized in practice.)

Negative Impacts:

- Slight to moderate risk of local groundwater contamination (particularly if contributing watershed is industrial or has heavy vehicular petroleum wash off).

- Infiltration basins provide some habitat value, but this is quite modest in comparison to that provided by pond systems. Failed basins provide better habitat than functioning basins.

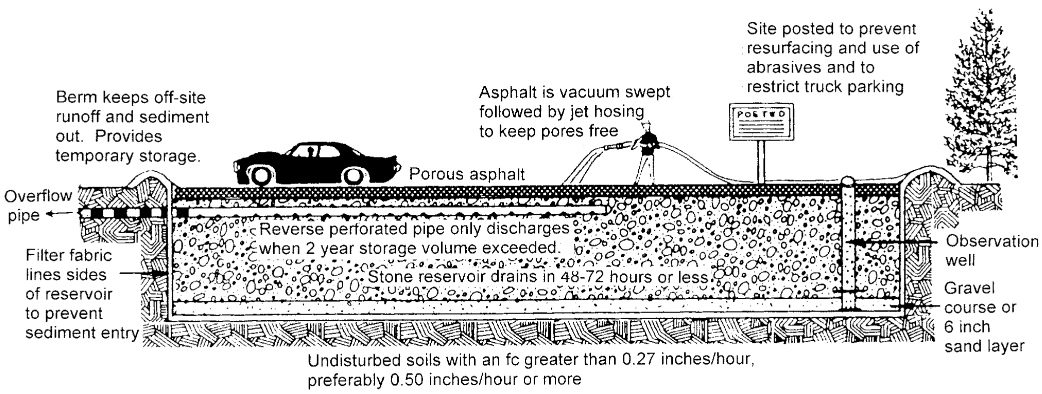
- Infiltration basins in close proximity to streams or lakes may degrade water quality if there is a rapid hydraulic connection between the basin and nearby surface water

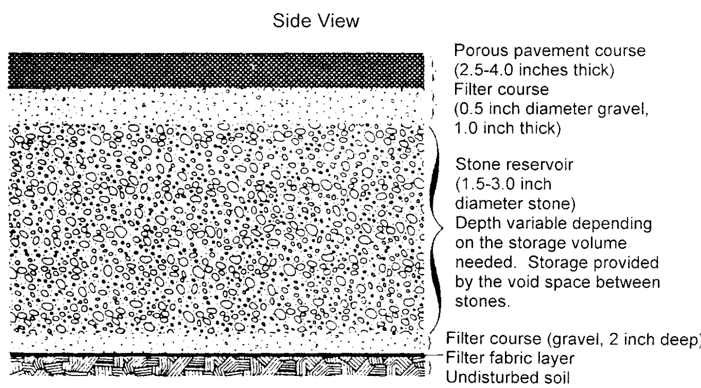
- May cause an increase in the local ground water table resulting in flooding of nearby basements. This is most likely to be a problem in areas of high existing ground water table.

Definition

Porous Pavement is an alternative to conventional pavement whereby runoff is diverted through a porous asphalt layer and into an underground stone reservoir. The stored runoff then gradually infiltrates into the subsoil.

Schematic Design of a Porous Pavement System





Source: Schueler, 1987

Pollutant Removal Capability:

Operating porous pavement systems have been shown to have high removal rates for sediment, nutrients, organic matter, and trace metals. The majority of the removal occurs as the result of the exfiltration of runoff into the subsoil, and subsequent adsorption or straining of pollutants within the subsoil.

Pollutant Removal Mechanisms: Include adsorption, straining, and microbial decomposition in the subsoil below the aggregate chamber, and trapping of particulate matter within the aggregate chamber. In addition, up to 90% of the annual rain fall volume is diverted to groundwater rather than surface runoff (Schueler, 1987).

Review of Monitoring Studies: Two monitoring studies have been conducted that indicate high long-term removal of sediment (up to 80%), phosphorous (up to 60%), and nitrogen (up to 80%), as well as high removal rates for trace metals and organic matter (39, 41). The majority of pollutant removal at porous pavement sites is due to the reduction of mass loadings via the groundwater. Measured concentrations of sediment, phosphorous, and nitrogen are only slightly reduced in the small, measured outflows from porous pavement.

Factors Influencing Pollutant Removal:

Positive Factors

- High exfiltration volumes
- Routine vacuum sweeping
- Maximum drainage time of two days
- Highly permeable soils
- Clean-washed aggregate
- Organic matter in subsoils
- Pretreatment of off-site runoff

Negative Factors

- Poor construction practices
- Inadequate surface maintenance
- Use of sand during snow conditions
- Low exfiltration volumes

Feasibility:

Feasibility: The use of porous pavement is highly constrained, requiring deep and permeable soils, restricted traffic, and suitable adjacent land uses.

Adaptability: Use of porous pavement may be restricted in regions with colder climates, arid regions or regions with high wind erosion rates, and in areas of sole-source aquifers.

Soils: Porous pavement is not practical in soils with field verified infiltration of less than 0.5 inches per hour. Soil borings must be taken two to four feet below the aggregate to identify any restricting layers.

Area: Most porous pavement sites are less than ten acres in size. This primarily reflects the perceived economic and liability problems associated with larger applications.

Slope: Less than five percent.

Depth to Bedrock and Water Table: Three feet minimum clearance from bottom of system.

Sole-Source Aquifer: Use of porous pavement should be evaluated carefully in regions where water is supplied by a single aquifer.

Traffic Volumes: Porous pavement is not recommended for most roadways and cannot withstand the passage of heavy trucks. Typically, porous pavement is recommended for lightly used satellite parking areas and access roads.

Sediment Inputs: Porous pavement is not advisable in areas expected to provide high levels of off site sediment input (e.g., upland construction, sparsely vegetated upland areas and areas with high wind erosion rates)

Cold Climates: While the standard porous pavement design is believed to withstand freeze/thaw conditions normally encountered in most regions of the country, the porous pavement system is very sensitive to clogging during snow removal operation (e.g., application of sand and de-icing chemicals and scraping by snow plows).

Use in Ultra-urban Areas: Some possibilities exist for the use of porous pavement during in-fill development provided that suitable soils are present,

Retrofit Capability: Extremely limited. Most soils in urbanized watersheds have been previously modified and so are not capable of providing adequate infiltration rates.

Storm Water Management Capability: Porous pavement sites can meet storm water management requirements in many cases.

Maintenance:

Quarterly vacuum sweeping and/or jet hosing is needed to maintain porosity. Field data however indicate that this routine maintenance practice is not frequently followed.

Longevity: Porous pavement sites have a high failure rate (75 %). Failure is due to partial or total clogging of the area that occurs:

- Immediately after construction
- Over time, when porous asphalt is clogged by sediment and oil
- When pavement is resurfaced with non-porous materials

Factors Influencing Longevity:

- Routine vacuum sweeping
- Use in low intensity parking areas
- Restrictions on access by heavy trucks, use of de-icing chemicals and sand
- Resurfacing
- Inspection and enforcement of specifications during construction
- Pretreatment of off-site runoff
- Extra-ordinary sediment control during construction

Failure Rates: Seventy-five percent of all porous pavement systems surveyed in Maryland have partially or totally clogged within five years. Failure has been attributed to inadequate construction techniques, low permeable soils and/or restricting layers, heavy vehicular traffic, and resurfacing with nonporous pavement materials. Some fraction of the clogged porous pavement sites could be rehabilitated with drop inlets and providing outlets from the aggregate chamber. The oldest operating porous pavement systems are about ten years old.

Potential Benefits/Concerns:

Positive Impacts:

- Porous pavement can divert large volumes of potential surface runoff to groundwater recharge and, in some cases, provide even greater recharge than pre-development conditions (OWML, 1986)

- Porous pavement can reduce downstream bank-full flooding

- Provides storm water quantity and quality treatment on-site, thereby protecting woodland, wetland, and stream valleys elsewhere on the site (Cahill, et. al., 1991)

Negative Impacts:

- Slight to moderate risk of groundwater contamination depending on soil conditions and aquifer susceptibility

- Possible transport of hydrocarbons from vehicles and leaching of toxic chemicals from asphalt/or binder surface

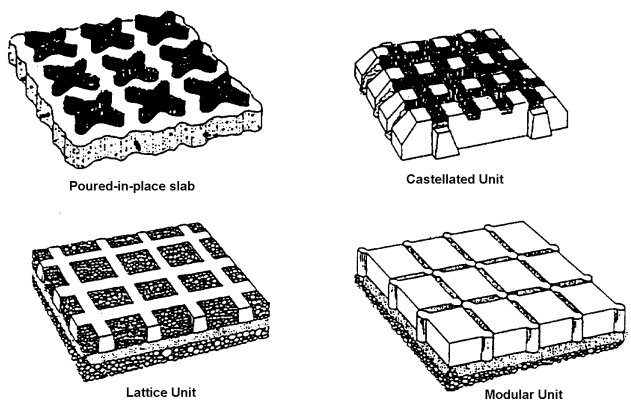
- The high failure rate of porous pavement sharply limits the ability to meet watershed storm water quality and quantity goals

CONCRETE GRID PAVEMENT BMP Fact Sheet #8

Definition

Concrete Grid Pavement is an alternative to conventional and porous pavement which acts like an infiltration system. Storm water percolates through voids in the concrete into the soils. Concrete is typically placed on a sand or gravel base, regularly inter-dispersed with void areas filled with pervious materials such as sand, gravel or grass. There are several concrete grid systems including concrete poured in place, precast concrete grids or modular pavers (Livingston, et. al., 1997). Plastic modular blocks are also available (Debo and Reese, 1995).

Schematic Design of a Concrete Grid Pavement System



Source: Watershed Management Institute, Inc. 1997

Pollutant Removal Capability:

Include adsorption, straining, and microbial decomposition in the sub-soil below the base material, and trapping of particulate matter within the base material. The annual rain fall volume is diverted to groundwater rather than surface runoff .

Pollutant Removal Mechanisms: Reduce surface water pollutant and sediment loading in runoff from parking lots or other surfaces through infiltration of storm water and runoff reduction.

Factors Influencing Pollutant Removal:

Positive Factors

- Peak flow control
- Groundwater recharge
- No additional land consumption

Negative Factors

- Requires regular maintenance
- Improper soils or slope
- Traffic restrictions
- Spills of hazardous materials may contaminate soils or ground water
- May be hazardous to wearers of high-heeled shoes

Feasibility:

Feasibility: Useful where permeable soils, low slopes and low traffic conditions are present.

Adaptability: Not suited to impermeable or shallow soils. High wind erosion areas and cold climates may also render the application unsuitable.

Soils: Concrete grid pavement is not practical in impermeable or shallow soils.

Area: Most concrete grid pavement sites are small in size.

Slope: Low.

Traffic Volumes: Concrete grid pavement is not recommended for most roadways and cannot withstand the passage of heavy trucks. Typically, concrete grid pavement is recommended for lightly used satellite parking areas and access roads.

Sediment Inputs: Concrete grid pavement is not advisable in areas expected to provide high levels of off site sediment input (e.g., upland construction, sparsely vegetated upland areas and areas with high wind erosion rates)

Cold Climates: May not perform well in extreme freeze/thaw conditions.

Retrofit Capability: Extremely limited. Most soils in urbanized watersheds have been previously modified and so are not capable of providing adequate infiltration rates.

Storm Water Management Capability: Concrete grid pavement sites can meet storm water management requirements in many cases.

Maintenance:

Concrete grid pavement has moderate to high maintenance needs. Paving blocks have an advantage over porous pavement in that they tend to seal less easily and replacing individual blocks is easier than patching porous pavement. However, they tend to be less able to withstand loads without misalignment.

"Good housekeeping" to minimize the introduction of particulates to the pavement.

Replacement of base and underlying soils if clogging occurs.

Fertilizers and pesticides should be used sparingly if turf is incorporated into the pavement since they may adversely affect ground water and concrete products.

Potential Benefits/Concerns:

Positive Impacts:

- Concrete grid pavement can divert large volumes of potential surface runoff to groundwater recharge and, in some cases, provide even greater recharge than pre-development conditions

- Concrete grid pavement can reduce downstream bank-full flooding

  Provides water runoff control without consumption of land.

Negative Impacts:

- Slight to moderate risk of groundwater contamination depending on soil conditions and aquifer susceptibility

- Possible transport of hydrocarbons from vehicles

Definition

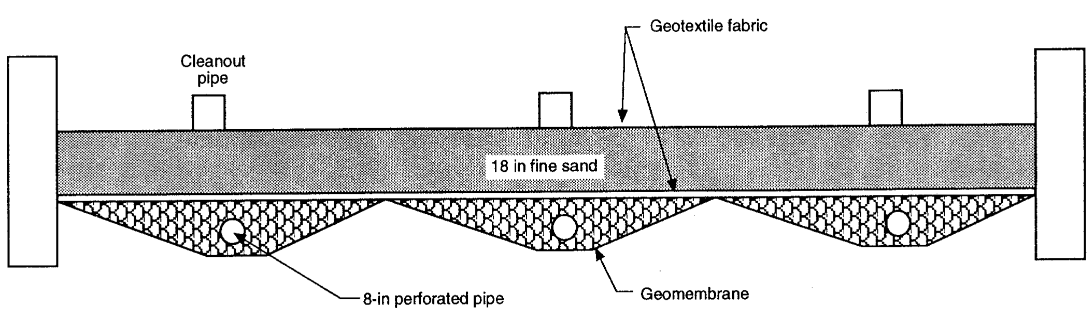
Sand filters are a relatively new technique for treating storm water, whereby the first flush of runoff is diverted into a self-contained bed of sand. The runoff is then strained through the sand, collected in underground pipes and returned back to the stream or channel. Storage is generally calculated on the runoff volume of 0.5 inches of rainfall per impervious acre (Debo and Reese, 1995).

Sand filters may be an “unconfined,” sand-filled trench with a perforated underdrain. There are also “confined” systems where the filter medium is contained in a concrete vault with a drain at the bottom of the vault. Depending on the specific design, these types of filters are often referred to as “Delaware Filters” or “Austin Filters” after the localities where they were initially designed or installed. Large sand filters are installed above ground and are self-contained sand beds that can treat storm water from drainage areas as much as five acres in size (NCSU, 1998).

Enhanced Sand Filters utilize layers of peat, limestone, leaf compost and/or topsoil, and may also have a grass cover crop. The adsorptive media of enhanced sand filters is expected to improve removal rates.

In addition, **sand-trench** systems have been developed to treat parking lot runoff.

Schematic Design of a Sand Filter System



Source: Austin, Texas 1991.

Pollutant Removal Capability:

Sand filter removal rates are high for sediment and trace metals, and moderate for nutrients, BOD and fecal coliform. The untested peat sand filter is projected to achieve significantly higher removal rates.

Pollutant Removal Mechanisms: Pollutant removal is primarily achieved by straining pollutants through the filtering medium (i.e., sand or peat) and by settling on top of the sand-bed and/or pretreatment pool. Additional nutrient removal can be accomplished by plant uptake if the filter has a grass cover crop.

Review of Monitoring Studies: Performance monitoring has been conducted on three sand filter systems in the Austin, Texas area (City of Austin, 1991). Average removal rates of 85% for sediment, 35% for nitrogen, 40% for dissolved phosphorus, 40% for fecal coliforms, and 50 to 70% for trace metals were reported. Negative removal was reported for nitrate-N which may reflect the nitrification process.

Slightly higher pollutant removal performance has been projected for peat sand filters due to the adsorptive properties of peat (Galli, 1990). The higher organic carbon (OC) content of peat would be expected to result in greater removal of dissolved metals and some increase in hydrocarbon removal. These are an estimated 50% for total nitrogen, 70% for total phosphorus and 90% for biological oxygen demand (BOD). The use of grass on the surface of a sand filter may also augment pollutant removal.

Factors influencing Pollutant Removal:

Positive Factors

- Off-line systems (City of Austin, 1991)
- Peat and/or limestone layer (Galli, 1990)
- Grass cover (City of Austin, 1991)
- Longer draw down times - 24 to 40 hours (City of Austin, 1991)
- Pretreatment pool (Galli, 1990)
- Minimum depth of 18 inches (City of Austin, 1991)
- Regular maintenance
- No direct connection to ground water

Negative Factors

- On-line systems (City of Austin, 1991)
- Freezing weather (Galli, 1990)

Feasibility:

Feasibility: Because sand filters are a self-contained man-made soil system, they can be applied to most development sites and have few constraining factors. Most sand filters have been used on small parking lots.

Adaptability: Sand filters have been successfully applied in Texas, Florida, Maryland, Delaware and Washington, DC. Performance of sand filters in colder climates is unknown. It is expected that sand filters would lose some or all of their filtering ability if they freeze. Once thawed they should function normally.

Climate: Sand filters are a very adaptable practice; they can be used on areas with thin soils, high evaporation rates, low soil infiltration rates, and limited space (City of Austin, 1988).

Watershed Size: The upper limit on sand filters appears to be about fifty acres; however, most have a contributing watershed between a half and ten acres. The Delaware parking lot sand trench (Shaver, 1991) is restricted to five acres or less.

Head Requirements: Two to four feet of available head needed for most off-line sand filter applications.

Use in Ultra-urban Areas: Sand filters and peat sand filters can be used to treat storm water runoff from small in-fill developments and from small parking lots (i.e., gas stations, convenience stores).

Retrofit Capability: Sand filters and peat sand filters have been designed as end-of-pipe retrofits in several applications. The Delaware sand filter system may be of particular value for older parking lots.

Storm Water Management Capability: Sand filters have a limited ability to reduce peak discharges; they are usually designed solely to improve water quality. Sand filters may be easily adapted into flood control BMPs.

Maintenance:

Maintenance Burden: Sand filters require frequent manual maintenance, primarily raking, surface sediment removal, and removal of trash, debris and leaf litter.

Longevity: Sand filters appear to have excellent longevity due to their off-line design and the high porosity of sand as a filtering media; however, relatively simple but frequent maintenance is required to maintain performance.

Factors Influencing Longevity:
- Quarterly maintenance of the sand filter to maintain porosity
- Flow splitter designs that will not clog frequently
- Pretreatment pool to remove excess sediment
- Adequate access to the sand filter
- Regular removal of surface sediments (frequency variable)

Most of the maintenance for sand filters is done by manual rather than mechanical means; consequently, the design should be oriented to make access and manual sediment removal as efficient as possible (City of Austin, 1991).

Failure Rates: Nearly 1,000 sand filters have been installed in the Austin, Texas area (City of Austin, 1991). According to the Austin Department of Public Works, the vast majority are working as designed and very few have failed. The oldest operating sand filter is almost ten years old. Sand filters been used effectively in dense urban areas within the District of Columbia and Austin, Texas, but they have not been widely applied elsewhere in the country (Troung, 1989).

Potential Benefits/Concerns:

Positive Impacts:
- Sand filters are useful in watersheds where concerns over groundwater quality prevent use of infiltration. Little or no wildlife habitat value is provided.

- Disposal of surface sediments from sand filters does not appear to be a problem. Testing by the Austin Department of Public Works indicates that the sediments are not toxic and can be land filled.

- Underground filters fit well into urban areas with restricted space (NCSU, 1998).

- Sand filters have very few environmental concerns because they are an off-line self-contained system.

Negative Impacts:
- Larger sand filter designs, without grass cover, may not be attractive in residential areas. The surface of sand filters can be extremely unattractive; some sand filters have caused odor problems.

- The concrete walls that surround the sand filter represent a safety hazard and thus should be fenced.

- Sand filters generally function only as a storm water quality practice and do not provide detention for downstream areas.

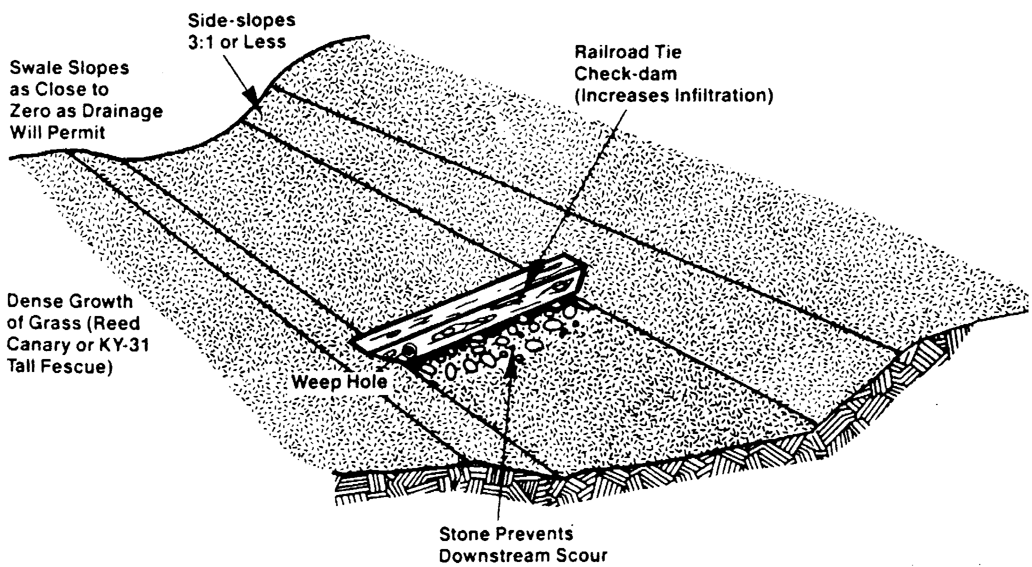
Definition

Conventional Grassed Swales are earthen conveyance systems in which, pollutants are removed from urban storm water by filtration through grass and infiltration through soil. Swales should be designed with relatively wide bottoms to promote even flow through the vegetation and avoid channelization, erosion, or high velocities.

In areas where grass is not easy to grow or maintain, rip rap lined channels may be considered an option (DRCOG, 1998).

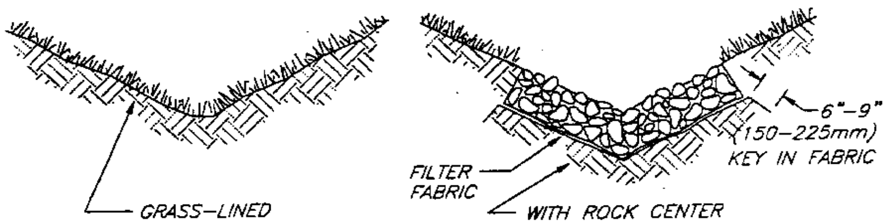
Enhanced Grassed Swales, or **Biofilters,** utilize check dams and wide depressions to increase runoff storage and promote greater settling of pollutants.

Schematic Design of an Enhanced Grassed Swale



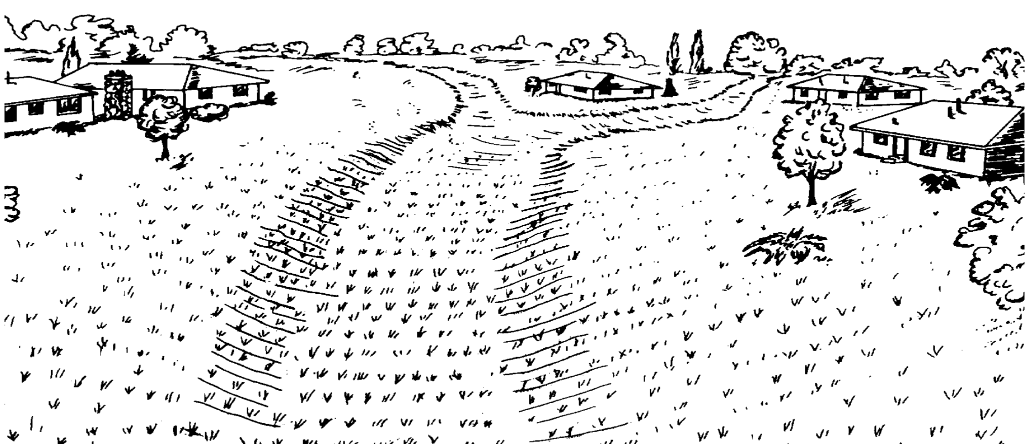
Source: Schueler, 1987.

Schematic Cross-section of Grassed Swales: without and with rock bottom



Source: Denver Regional Council of Governments, 1998

Schematic of Urban Swale:



Source: USDA, 1978

Pollutant Removal Capability:

Conventional grassed swale designs have achieved mixed performance in removing particulate pollutants such as suspended solids and trace metals. They are generally unable to remove significant amounts of soluble nutrients. Biofilters that increase detention, infiltration and wetland uptake within the swale have the potential to substantially improve swale removal rates.

Pollutant Removal Mechanisms: Grassed swales act to remove pollutants by the filtering action of grass, by settling, and in some instances, by infiltration into the subsoil.

Review of Monitoring Studies: The pollutant removal capability of ten conventional residential and highway swale systems has been monitored by six researchers (Woodward-Clyde, 1991). The results are mixed. Half of the swales studied demonstrated a moderate to high pollutant removal capability and the other half showed no removal or negative removal (MWCOG, 1983).

The expected removal efficiency of a well-designed, well-maintained conventional swale is projected to 70% for total suspended solids, 30% for total phosphorus, 25% for total nitrogen, and 50 to 90% for various trace metals. Swales appear to be more effective at removing metals than nutrients; a number of researchers have observed trace metal accumulation in swale sediments (46, 47). Some evidence has also been offered that resuspension or remobilization of nutrients may occur (Dorman, et. al., 1989). No performance data exits on the effect of check dams in swales; however, the detention and trapping capability that they add is projected to be quite useful (Schueler, 1987).

Factors Influencing Pollutant Removal:

Positive Factors

- Check dams
- Low slopes
- Permeable subsoils
- Dense grass cover
- Long contact time
- Smaller storm events
- Coupling swales with plunge pools, infiltration trenches or pocket wetlands
- Swale length greater than two hundred feet

Negative Factors

- Compacted subsoils
- Short runoff contact storms
- Large storm events
- Snow melt events
- Short grass heights
- Steep slope (6% or greater)
- Runoff velocities greater than 1.5 fps
- Peak discharge greater than 5 cfs
- Dry weather flow

Feasibility:

Feasibility: Swales can provide sufficient runoff control to replace curb and gutter in single-family residential subdivisions and on highway medians; however, their ability to control large storms is limited. Therefore, in most cases, swales must be used in combination with other BMPs downstream.

Adaptability: Swale performance diminishes sharply in highly urbanized settings. Also, swales should generally not receive construction site runoff.

Contributing Watershed Area: Grassed swales can only be applied in areas where maximum flow rates are not expected to exceed 1.5 fps (Horner, 1988). The suitability of a swale at a site will depend on the area, slope and imperviousness of the contributing watershed as well as the dimensions and slope of the swale system.

Dry-Weather Flow: Pollutant removal will be reduced if dry-weather flow is present in the swale.

Peak Discharge: Swales generally do not have the capacity to control runoff effectively in areas where peak discharge exceeds 5 cfs or where velocity is over 3 fps. To decrease velocity, the swale should be designed to be as wide as available space allows.

Construction Areas: The high sediment loads from unstabilized construction sites can overwhelm the system.

Climate: Grassed swales can be used in all regions of the country where climate and soils permit the establishment and maintenance of dense vegetative cover. The performance of swales in removing pollutants may be reduced in regions with long, cold winters and snow melt conditions, particularly where salts and other de-icing chemicals are applied or where snow plowing scrapes the shoulder. In arid climates careful selection of plant species or occasional irrigation may be required.

Soils: Swales may be less effective in regions with sandy soils (Sandy soils make it difficult to maintain the side slopes of the swale.)

Slope: To increase infiltration rates, longitudinal slopes should be as close to zero as possible and not greater than five percent (Schueler, 1987).

Grass Height: A vertical stand of dense vegetation higher than the water surface is most effective (a minimum of six inches) (SEWRPC, 1991). Vegetation should be chosen based on the conditions expected in the swale (ie: frequent inundation or prolonged periods of dry weather).

Swale Contact Time: In general, pollution removal capacity increases with contact time of runoff through the swale. Swale contact time varies with the depth, width and length of the swale as well as longitudinal slope and type of vegetation. Any one of these variables or sets of variables can be manipulated to meet water quality objectives. In addition, check dams can further increase contact time (Horner, 1988).

Use in Ultra-urban Areas: It is very difficult to prevent erosion in swales located in highly impervious, ultra-urban areas.

Retrofit Capability: Many residential developments and highways have existing grass channels. An attractive retrofit option is to install check dams to increase contact time and promote settling using portable weirs.

Storm Water Management Capability: Conventional grassed swales are primarily a storm water conveyance system and rarely provide sufficient detention to attenuate storm flows. The exception is when detention storage is provided behind check dams in very long swale systems.

Maintenance:

Mowing and periodic sediment clean out are the primary maintenance activities. In residential subdivisions, adjacent homeowners will undertake these responsibilities. Also, inspection after large storms for erosional failures and special maintenance should occur regularly.

Longevity: Conventional swales can last an indefinite period of time if properly designed, periodically mowed, and if sediment deposits are removed from time to time.

Factors Influencing Longevity:

- Runoff velocity that is consistently high (i.e., > 5 fps) will increase the tendency for the swale to erode

- The rate of erosion also diminishes as side slopes become flatter (Horner, 1988)

Failure Rates: Surveys by Horner (1988) and in the Washington, D.C. area indicate that the vast majority of conventional swales operate as designed with relatively minor maintenance (grass mowing). The primary maintenance problem is the gradual build-up of soil and grass adjacent to roads which prevents entry of runoff in swales. Gully erosion is not a problem in well-designed swales in areas where climate permits the establishment of a dense turf.

Potential Benefits/Concerns:

Positive Impacts:

- When grassed swales are substituted for curbs and gutters, they can slightly reduce impervious areas, and more importantly, eliminate a very effective pollutant collection and delivery system

- Low slope swales can create wetland acreage

- Unmowed swale systems that are not adjacent to roadways can provide valuable "wet meadow" habitat

- Swales can act to partially infiltrate runoff from small storm events if underlying soils are not compacted

- Swales eliminate curbs and gutters and provide some infiltration and habitat benefits.

Negative Impacts:

- Culverts may leach trace metals into runoff

- Lawn fertilization may increase runoff nutrient levels

- Possible impact on local groundwater quality

- Standing water in residential swales will not be popular with adjacent residents for aesthetic reasons and because of potential safety, odor and mosquito problems.

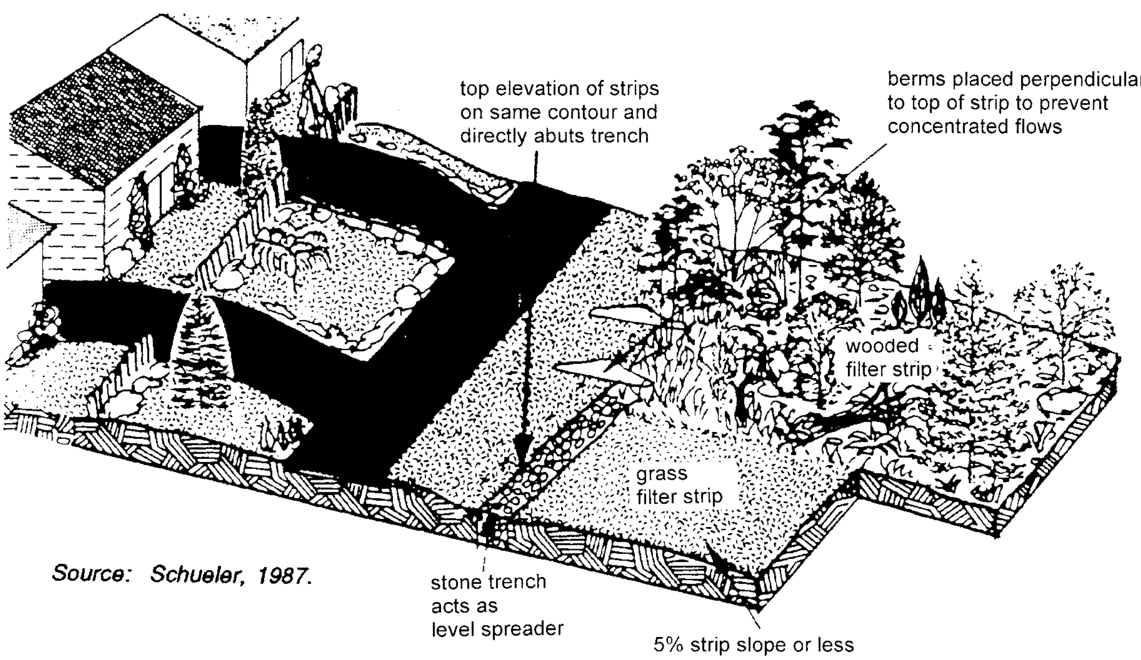
Definition

Filter Strips are vegetated sections of land designed to accept runoff as overland sheet flow from upstream development. They may adopt any natural vegetated form, from grassy meadow to small forest. The dense vegetative cover facilitates pollutant removal. **Filter strips** cannot treat high velocity flows; therefore, they have generally been recommended for use in agriculture and low density development.

Filter strips differ from **natural buffers** in that strips are not "natural;" rather, they are designed and constructed specifically for the purpose of pollutant removal. A filter strip can also be an **enhanced natural buffer,** however, whereby the removal capability of the natural buffer is improved through engineering and maintenance activities such as land grading or the installation of a level spreader.

Filter strips also differ from **grassed swales** in that swales are concave, vegetated conveyance systems, whereas **filter strips** have fairly level surfaces.

Schematic Design of a Filter Strip



Source: Schueler, 1987.

Pollutant Removal Capability:

Filter strips can effectively reduce particulate pollutant levels, e.g. sediment, organic materials and trace metals, in areas where runoff velocity is low to moderate; however, studies show that, under these same conditions, their ability to remove soluble pollutants is highly variable.

Pollutant Removal Mechanisms: Pollutants are removed by the filtering action of vegetation, deposition in low velocity areas, or by infiltration into the subsoil. Length, slope, soil permeability, and vegetative density influence the effectiveness of filter strips.

Review of Monitoring Studies: Two studies of filter strips in urban areas have indicated that filter strips do not trap pollutants efficiently in urban settings due to high runoff velocity (Woodward-Clyde, 1991). Of these studies, one is ongoing and final results are not yet reported. The other study indicated an average total suspended solids removal rate of only 28 % and did not report removal rates for either total nitrogen or total phosphorus.

Research to date on vegetated filter strips has largely focused on filter strips in agricultural settings. Most of these studies indicate that, when functioning properly, filter strips can remove particulate pollutants with some reliability, but are less dependable for nutrient removal. The relative effectiveness of forested versus grassed filter strips has not been determined. Nor is the effect of mowing on pollutant removal known.

Factors Influencing Pollutant Removal:

Positive Factors

- Minimum strip width of fifty feet (Schueler, 1987)
- Slope of 5% or less (Schueler, 1987)
- Forested filter strips
- Clay soil or organic matter surface (IEP, Inc., 1990)
- Contributing area of less than 5 ac (Schueler, 1987)
- Grass height of 6 to 12 inches (SEWRPC, 1991)
- Sheet flow

Negative Factors

- Runoff velocity >2.5 fps, depending on site conditions (Horner, 1988)
- Slopes greater than 15%
- Hilly terrain
- Unmowed filter strips

Feasibility:

Feasibility: Vegetated filter strips have limited feasibility in highly urbanized areas where runoff velocities are high and flow is concentrated. Therefore their use is primarily restricted to low and medium density residential areas where they can accept rooftop runoff and runoff from pervious areas such as lawns.

Adaptability: Filter strips do not provide adequate pollutant removal on slopes over fifteen percent; moreover, they require climates that can sustain vegetative cover on a year-round basis. Furthermore, contributing upland areas must be small (one to five acres) so that runoff arrives at the filter strip as overland sheet flow. The incorporation of a level spreader into the design may enhance pollutant removal. Use of native vegetation or vegetation appropriate for the local climate, is essential to enhance plant survival.

Contributing Watershed Area: To prevent concentrated flows from forming, maximum contributing area to an individual filter should be less than five acres.

Land Use: In urban settings, it is likely that filter strips will be most effective in treating rooftop runoff and runoff generated from lawns and other pervious areas. Filter strips should not be used to control large impervious areas, such as parking lots.

Peak Discharge Rates: High flow velocity will prevent the strip from trapping pollutants and will cause erosion and channelization.

Soils: The ability of filter strips to remove nutrients from surface runoff improves where clay soils or organic matter are present.

Length: Minimum length should be no less than fifty to seventy-five feet plus four feet for any one percent increase in slope.

Depth to Water Table: Greater removal of soluble pollutants can be achieved where the water table is within three feet of the surface, i.e. within the root zone.

Use in Ultra-urban Areas: The high percentage of impervious surface, which creates high peak discharge rates limits the usefulness of this practice as a water quality control in ultra-urban settings.

Retrofit Capability: Retrofit is relatively simple if enough land area is available to adequately service the contributing watershed area, and soil and slope conditions are favorable.

Storm water Management Capability: Filter strips cannot reduce peak discharges to predevelopment levels. They function primarily as a water quality BMP. The limited ability of filter strips to control runoff and to remove nutrients suggests their most effective use is in combination with pretreatment and detention systems.

Maintenance:

Filter strips require periodic repair, regrading and sediment removal to prevent channelization. Sediment frequently collects in a berm at the upper edge of the strip. Replanting and reseeding may be required periodically. Grassy strips in residential areas may also need mowing. Inspections and corrective maintenance, such as weeding or replanting should take place more frequently in the first couple of years to assure stabilization. Removal of dead vegetation may also improve strip performance.

Longevity: Urban filter strips that are not regularly maintained may quickly become nonfunctional. Field studies indicate that strips tend to have short life spans because of lack of maintenance, improper location and poor vegetative cover.

Factors Influencing Longevity:

- Use of a level spreader at the top of the strip will help to distribute flow evenly as well as protect the strip from man-made damage.

- Regular removal of sediment will help to maintain the original filtration capacity of the strip as well as assure that build-up of sediment does not alter design features such as contour or slope.

- Periodic repair of eroded areas and regrading around the strip may be necessary to assure that flows do not concentrate through or around the strip.

- Periodic weeding and replanting, particularly in the first few years of life, will allow the vegetative cover to stabilize and become permanent.

- If a filter strip is used for sediment control, it should be reseeded and regraded after construction.

Failure Rates: Studies in agricultural settings (21, 51), where peak discharge rates tend to be much lower, show that filter strips have generally failed when:

- Design slope has exceeded the recommended fifteen percent

- Design width of slopes has been too narrow to adequately service the contributing area

- Strips have poor vegetative cover

- Uneven terrain has caused channelization.

In a study of thirty-three farms in Virginia, researchers found that the majority of filter strips in use were ineffective because most flow had become channelized (Horner, 1988).

The study suggests, moreover, that poor design or maintenance may cause a strip to fail within a fairly short period of time (six months or less).

Potential Benefits/Concerns:

Positive Impacts:

- Filter strips can be combined with stream buffers to protect the riparian corridor
- Groundwater recharge
- Urban wildlife habitat
- Streambank stabilization and erosion control
- Aesthetically pleasing
- Can serve as a buffer between incompatible uses

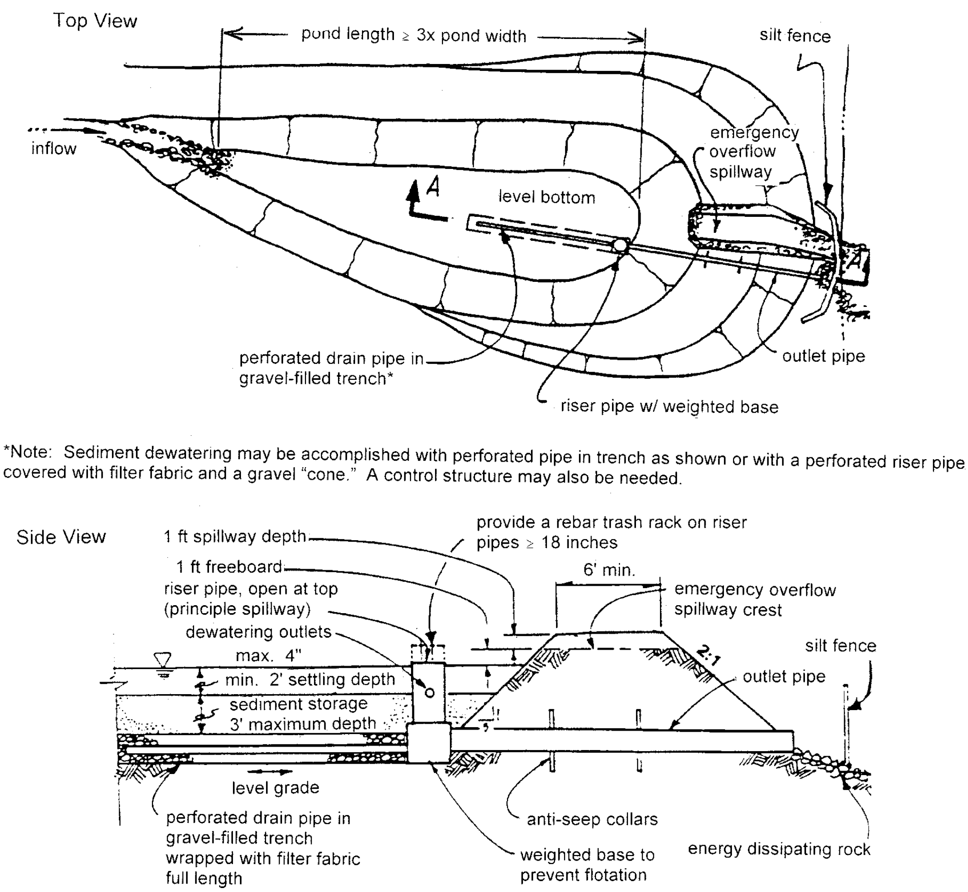
Negative Impacts:

- Few

Definition

Sediment Traps are small impoundments that allow sediment to settle out of runoff water. Sediment traps are typically installed in a drainage way or other point of discharge from a disturbed area (Horner, et. al., 1994).

Schematic Design of a Sediment Trap



Source: Washington Dep. Ecol. 1992.

Pollutant Removal Capability:

Effective at removal of large particulates in sediment, primarily in size from silts to sands.

Pollutant Removal Mechanisms: Removes sediment by slowing water velocity allowing for sediment settling by trapping it in ponding water. Settling ability is related to the square of particle size. Halving particle size quadruples the time needed to achieve settlement.

Factors Influencing Pollutant Removal:

Positive Factors	Negative Factors
• Low slopes	• Concentrated flows
• Small area	• Poor construction

Feasibility:

Feasibility: Not effective against concentrated flows or in areas with a slope greater than 3 to 1. Traps do not filter non-sediment pollutants.

Adaptability: Primarily effective as a short term (18-24 months) solution to conditions such as construction. Effective on areas of less than five acres.

Contributing Watershed Area: Sediment traps are easily adaptable to many conditions, including thin soils and steep slopes. A large contributing area may require large or multiple sediment traps (DRCOG, 1998).

Development Feasibility: Suitable to construction areas where more permanent erosion control techniques have not yet been established.

Storm Water Management Capability: Not suited to concentrated flows.

Maintenance:

Regular maintenance includes outlet checking and sediment removal.

Longevity: Basin traps require maintenance of drainage pipe systems and sediment removal from the basin to maintain effectiveness and function.

Factors Influencing Longevity:

- Regular removal of sediment will help to maintain the ponding capacity so that build-up of sediment does not alter design allowing breaching.

Failure Rates: Traps fail when breaching or short-circuiting occurs, through poor construction or lack of maintenance of the outlet.

Potential Benefits/Concerns:

Positive Impacts:

- Reduction of large particle sediment in surface waters.

Negative Impacts:

- Not as effective as other erosion control techniques in removing small particle sediments.

- Does not provide filtration of non-sediment pollutants.

WIND EROSION CONTROLS — *BMP Fact Sheet #13*

Definition:

Wind Erosion Controls limit the movement of dust from disturbed surfaces and may include many different practices. Different materials such as wood fence, snow fence, vegetation (trees and shrubs) and straw bales may be used as barriers. Sprinkling areas with water may also be used.

Pollutant Removal Capability:

Wind erosion control practices are designed to prevent airborne sedimentation. Vegetative windbreaks also serve a soil stabilization function.

Feasibility:

Feasibility: Wind erosion control practices can be applied to construction sites and other areas where loss of vegetation has occurred.

Adaptability: Can be adapted in all areas where high winds are an environmental condition. In arid climates, vegetative controls may require irrigation.

Development Feasibility: Useful in areas where natural or manmade (buildings, wood fences) windbreaks do not exist.

Use in Ultra-urban Areas: Not useful in developed areas.

Retrofit Capability: May be developed in existing open space areas.

Storm Water Management Capability: Does not directly influence storm water runoff, although wind erosion can be a cause of sedimentation in runoff.

Maintenance:

Trees and Shrubs: Weeding in the first years after installation will enhance tree survival. Periodic pruning is necessary to long term performance and appearance. Dead, damaged or diseased trees should be replaced.

Other structures: Require periodic maintenance to replace damaged areas.

Longevity: Dependant upon maintenance.

Failure Rates: Poor maintenance or inappropriate placing of controls with respect to prevailing winds contribute to poor performance.

Potential Benefits/Concerns:

Positive Impacts:

- Lowers sedimentation resulting from runoff (USEPA, 1992)
- Controls airborne soil and other particulates, improving air quality
- Wind erosion control along roads and highways may reduce snow removal costs and enhance driver safety.

Negative Impacts:

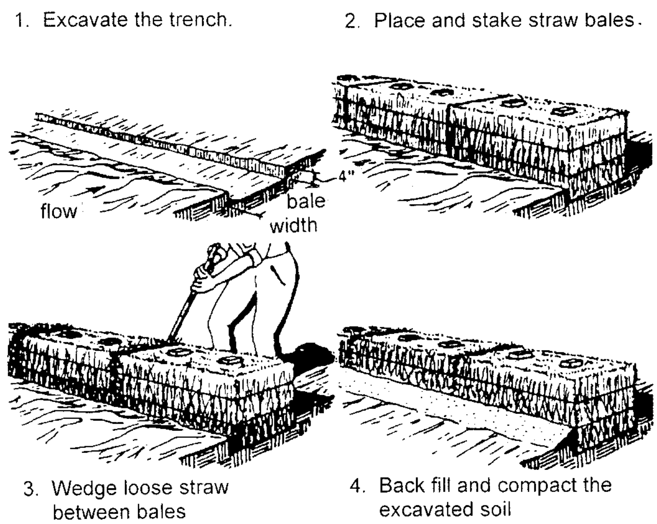
- Excessive sprinkling may result in non-storm water discharges from site (USEPA, 1992)

Definition

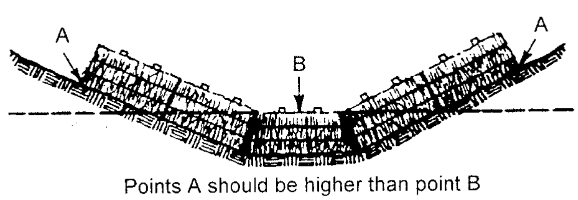
Check Dams are small, temporary dams constructed across a swale or channel. They are generally constructed of hay or straw bales gravel or rock.

Silt Fence is designed to slow runoff so sediment settles. It is available in several mesh sizes. Silt fence may also be referred to as filter fence.

Schematic Design for a Hay/Straw Dam



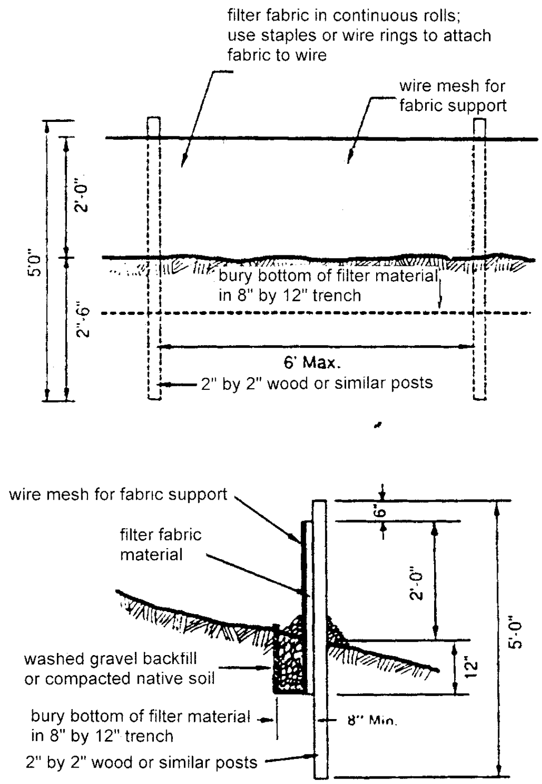
Construction of a Straw Bale Barrier



Proper Placement of Straw Bale Barrier in Drainage Way

Source: Washington Dep. Ecol. 1992.

Schematic Design for a Silt Fence



Source: Washington Dep. Ecol. 1992.

Pollutant Removal Capability:

Effective against large particle sediment, primarily sands and larger silts if installed correctly.

Pollutant Removal Mechanisms: Sediment settling through pooling of water to slow velocity.

Factors Influencing Pollutant Removal:

Positive Factors

- Temporary control measure
- Large particle removal
- Proper installation to reduce piping

Negative Factors

- Concentrated or high velocity flows
- Hay is attractive to livestock and wildlife which will shorten check dam life
- Silt fence may be knocked down by livestock or wildlife

Feasibility:

Feasibility: Suitable to short term large particle sediment control in barren areas such as construction sites. Not suited to concentrated flows, slopes greater than 2 to 1 or large areas.

Adaptability: Due to the limited life span of hay/straw bales and silt fence these methods are not suited to long term uses.

Contributing Watershed Area:

> Hay/straw bales - maximum of 0.25 acres per 100 feet of fence length with a 2:1 or shallower slope and 100 foot slope length.
>
> Silt fence - Maximum of 1 acre for a single fence. Gradient should not exceed 1:1 and slope length should be 100 feet or less (Horner, et. al., 1994).

Development Feasibility: Appropriate on construction sites and other areas where temporary measures are needed. Not feasible as a long term solution.

Use in Ultra-urban Areas: Useful at urban construction sites.

Storm water Management Capability: Removes large sediment particles only. Not appropriate management of concentrated flows.

Maintenance:

Regular maintenance is necessary to repair breaks and breaches. Sediment removal may also be necessary. Livestock and wildlife may find hay bales attractive necessitating more frequent replacement.

Longevity: Three months for hay/straw dams and six to twelve months for silt fence.

Factors Influencing Longevity:

- Silt fence and bale checks must be trenched into the soil to operate effectively.
- Construction practices and experience with local conditions.
- Regular inspection and maintenance practices.

Failure Rates: Regular maintenance and/or replacement is necessary to maintain effectiveness.

Potential Benefits/Concerns:

Positive Impacts:

- Partial reduction in sediment loads as large particles are removed.

Negative Impacts:

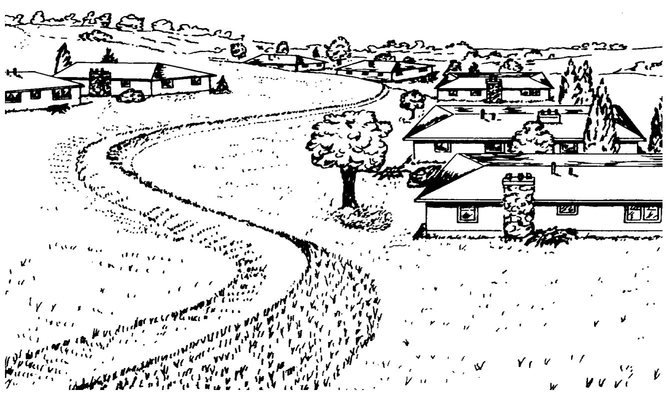
- Does not contribute to small particle sediment reduction.
- Not effective against other pollutants.

STEEP SLOPE DIVERSION TERRACES ***BMP Fact Sheet #15***

Definition

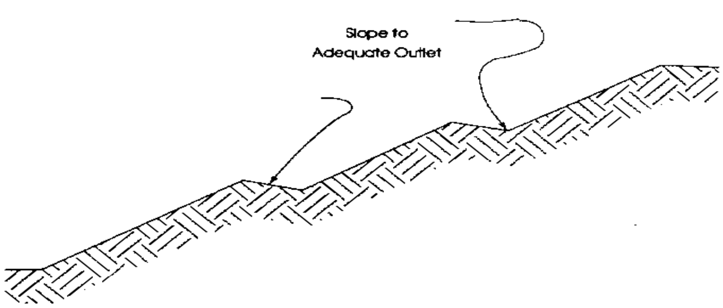
Steep Slope Diversion Terraces break up a slope by providing areas of low slope in the reverse direction, keeping water from proceeding down slope at increasing volume and velocity. Terraces generally direct flow across a vegetated, steep slope to a stable outlet (Dodson, 1995).

Schematic Design for Steep Slope Terraces



Source: USDA, 1978

Schematic Cross-Section Steep Slope Terraces



Source: EPA, 1992

Pollutant Removal Capability:

Can provide removal of sediments from runoff. Degree of success is determined by steepness of the terraced flow paths and velocity of flow.

Pollutant Removal Mechanisms: Slowing of water velocity to achieve settling of sediment and reduce down slope erosion.

Factors Influencing Pollutant Removal:

Positive Factors	Negative Factors
• Soil loss control	• Steep slopes

Feasibility:

Feasibility: Can be used on slopes too steep for other sediment control measures.

Adaptability: Can be adapted in rural and urban settings.

Contributing Watershed Area: Can be used on larger, steeply sloping watersheds if adequately designed.

Development Feasibility: Can be used in rural and agricultural settings as well as urban construction and other steep slope areas where high water velocity causes erosion.

Use in Ultra-urban Areas: Suitable to urban use.

Retrofit Capability: Sites with long, steep slopes can benefit from retrofitting.

Storm Water Management Capability: Can aid sediment removal through velocity reduction in runoff.

Maintenance:

Maintenance is required to repair areas weakened by high flows. Concentrated flows may break terrace design.

Longevity: Can provide long term control with adequate maintenance.

Potential Benefits/Concerns:

Positive Impacts:

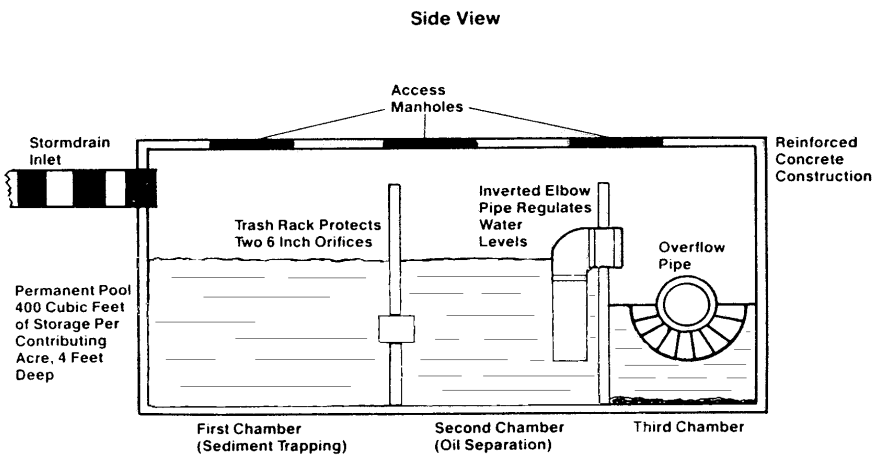
- Erosion and sediment control through water velocity control.

WATER QUALITY INLETS/ OIL-WATER SEPARATORS *BMP Fact Sheet #16*

Definition

A **Water Quality Inlet** is a three-stage underground retention system designed to remove heavy particulates and small amounts of petroleum products from storm water runoff. Also known as an **Oil/grit Separator** or an **Oil-water Separator**. As water flows through the three chambers, oils and grease separate either to the surface or to sediments and are skimmed off and held in the catch basin or storage tank. The storm water then passes on to the sanitary sewer, storm sewer or into another storm water pollution control device (NCSU, 1998).

Schematic Design for Water Quality Inlet Oil Grit Separator



Source: Schueler, 1987.

Pollutant Removal Capability:

Current designs of water quality inlets trap coarse-grained sediments and small amounts of oil. Removal of silt, clay, nutrients, trace metals, soluble pollutants and organic matter is expected to be slight. Pollutant removal also depends on the basin volume, flow velocity, and the depth of baffles and elbows in the chamber design (NCSU, 1998). Water quality inlets may function best as a first stage in the treatment of storm water.

Soaps, detergents, some alcohols, and other agents that emulsify oils significantly decrease the effectiveness of oil-water separators. Emulsified oil remains mixed with influent water and passes through the separator rather than being detained.

Re-suspension also appears to limit long-term sediment removal. Actual removal only occurs when inlets are cleaned out. An effective clean-out and disposal schedule is essential.

Under no circumstances should water quality inlets or oil-water separators be used to dispose of waste oil or other petroleum products.

Pollutant Removal Mechanisms: Gravitational settling within the first two chambers can achieve partial removal of grit and sediments. Hydrocarbon removal is based on the relatively low solubility of petroleum products in water and difference between the specific gravity of water and the petroleum compounds. Oil-water separators are not designed to separate other products such as solvents, detergents or metals. Actual pollutant removal is accomplished when trapped residuals are cleaned out of the inlet (Schueler, 1987).

Review of Monitoring Studies: Recent field studies confirm the limited effectiveness of water quality inlets (Shepp, et. al., 1992). For example, the average depth of sediments trapped in over 120 water quality inlets was less than two inches, and more than eighty percent of the trapped sediments were coarse grained grit and organic matter. Sediment accumulation did not increase with time, suggesting that re-suspension was a significant problem. Regular cleaning is necessary. Water quality inlets did trap floatable debris, and the sediments trapped (average of 10 cubic feet per structure) were extremely oily in nature (Galli, 1992).

Factors Influencing Pollutant Removal:

Positive Factors

- Off-line designs
- Adsorptive media (peat, sand)
- Adsorptive pads (for oil)
- Elevated orifices between chambers one and two
- Baffle plates
- Other methods to prevent resuspension
- Regular clean-out
- Long residence time

Negative Factors

- On-line systems
- Low volume
- Oil dumping
- Low orifices
- Presence of soaps, detergents or other emulsifying agents

Feasibility:

Feasibility: Inlets are restricted to small, highly impervious catchments of two acres or smaller (such as gas stations, parking lots, fast food outlets, and convenience stores).

Adaptability: Inlets can be adapted to all regions of the country.

Physical Factors: Water quality inlets can be applied in most small development situations, such as parking lots, gas stations, convenience stores, and along some road-ways. The primary limitation is contributing area. Most systems are applied to contributing watershed areas of two acres or less. The contributing areas typically are mostly or entirely impervious. The inlet must be connected to the storm drain, sanitary line or to additional storm water treatment measures.

Use In Ultra-Urban Areas: Water quality inlets are frequently applied in ultra urban areas, where space or storage are not available for other, more effective urban BMPS.

Retrofit Capability: Very limited. Low removal capability coupled with disposal problems limits the utility of the water quality inlets as a retrofit practice.

Storm Water Management Capability: None. Limited storage of water quality inlets cannot meet storm water requirements.

Maintenance:

Inlets require inspections and clean-outs to remove accumulated sediment, oils, floatables and other pollutants. Wastes removed from these systems should be tested to determine proper disposal methods. The wastes may be hazardous; therefore, maintenance budgets should include provisions for proper disposal (NCSU, 1998). Inlets may be difficult to clean and maintain because of its enclosed, underground design (NCSU, 1998). Above ground designs do exist, though they may not be practical in cold Wyoming winters.

Depending on the type of pollutants entering an oil-water separator and the configuration of the separator, they may be regulated by one or more federal, state or local programs. A brief description of possible state or federal regulation follows. Be sure to check with appropriate agencies before installing a new facility. Sludge recovered from oil-water separators may be, if hazardous, regulated by the Wyoming Department of Environmental Quality (DEQ) and/or the federal Environmental Protection Agency (EPA). Separators that include a separate tank to store waste petroleum products face additional regulations in that the waste oil tank is regulated as an underground storage tank. Existing oil-water separators that are tied to a septic system are considered class V underground injection control systems and regulated by DEQ. New connections to septic systems are no longer allowed. If you are considering an oil-water separator please contact DEQ and your local government agencies for further information.

Longevity: Longevity of water quality inlets is high. Over ninety-five percent of all inlets are operating as designed in their first five years of operation.

Factors Influencing Longevity: The basic design is very robust, and very few structural or clogging problems appear to have occurred in the first five years of operation; however, regular clean-outs are not being performed at the vast majority of inlets (Galli, 1992). Therefore, the actual pollutant removal is very low at present.

Failure Rates: Nearly four hundred water quality inlets have been installed in the Baltimore/Washington area. Field studies of over one hundred water quality inlets indicated that over ninety-five percent are operating as designed, and very few clogging problems have been noted (Galli, 1992). The oldest operating inlets are five years old.

Potential Benefits/Concerns:

Positive Impacts:

- Trapping of floatable trash and debris
- Potential reduction of hydrocarbon load from areas with high traffic/parking use

Negative Impacts:

- Potential toxicity of trapped residuals
- Possibility of pulse hydrocarbon loadings due to re-suspension during large storms
- In some regions, it may be difficult to find environmentally acceptable disposal methods.

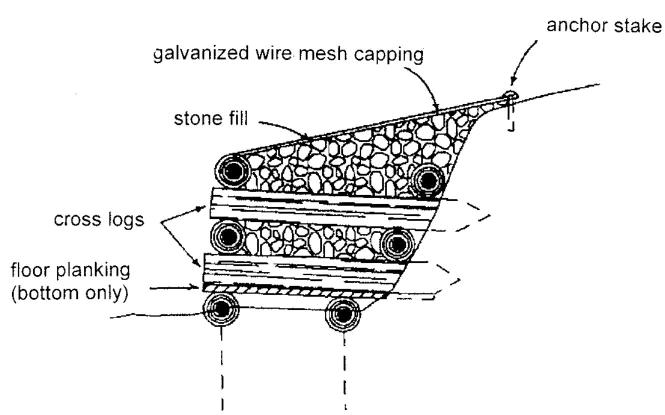
Definition:

Streambank Stabilization controls erosion through management of water velocity and/or stream bank stability by natural and manmade controls to decrease bank erosion and sediment loading in waterways. Structural or vegetative means may be used separately or together.

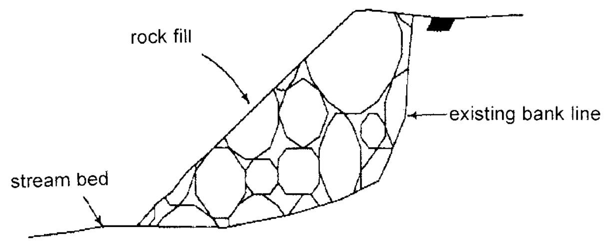
Structural Streambank Stabilization decreases erosion by deflecting water energy away from the streambank. Methods include gabion baskets, rip rap, slope paving, log cribbing as well as in-channel diversion structures (Dodson, 1995).

Vegetative Streambank Stabilization, also known as **Bioengineering** or **Soil Bioengineering**, describes several methods of establishing vegetative cover by embedding a combination of live, dormant and/or decaying plant materials into banks and shorelines (TBG, Inc., 1998).

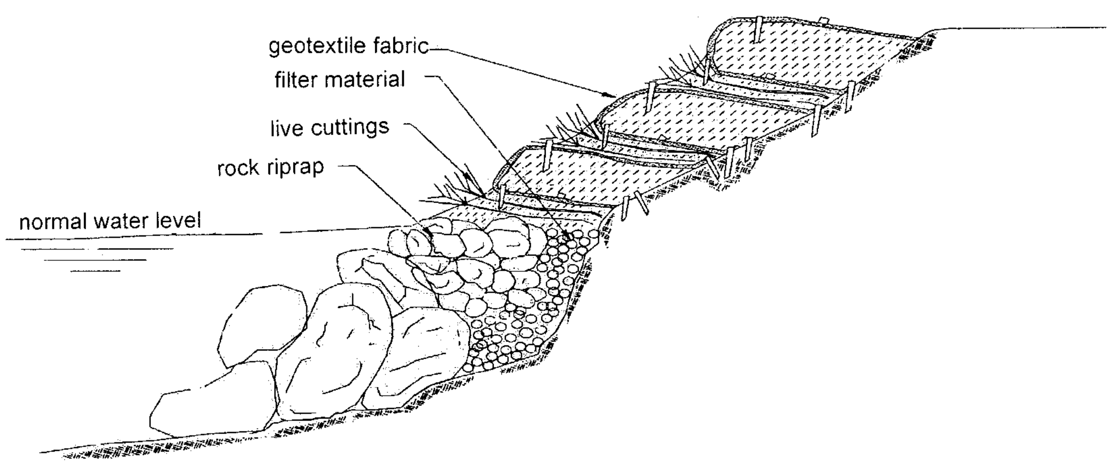
Schematic Designs for Streambank Stabilization Controls



Log Cribbing
Source: Dodson, 1995



Rock Rip Rap
Source: EPA, 1992



Bioengineering
Source: USDA, 1994

Pollutant Removal Capability:

Rather than pollutant removal, functions by removing a source of sediment.

Pollutant Removal Mechanisms: Pollutant reduction is achieved through sediment avoidance by stabilizing streambanks which are subject to erosion during storm events. Vegetative barriers may also filter overland runoff. Additionally, methods that reduce velocity may remove sediment from the stream through deposition.

Feasibility:

Feasibility: Natural or manmade corrective action can be applied to any stream or river bank where erosion is occurring. In-stream work may require state or federal permits. Use of debris (such as asphalt, refrigerators, etc.) are generally not acceptable for rip rap.

Adaptability: May be used in rural and urban settings.

Development Feasibility: Applicable to areas where erosion has occurred within streambanks due to high water velocity and scouring.

Use in Ultra-urban Areas: May be used as a control method where erosion is threatening property or roadways.

Retrofit Capability: Application to existing problem areas can be made.

Storm Water Management Capability: Indirectly manages storm water by managing the effects of storm water draining into creeks and rivers (TBG, Inc., 1998).

Maintenance:

Periodic maintenance may be required to maintain effectiveness.

Longevity: Installed and maintained correctly, can provide long term sediment load avoidance.

Factors Influencing Longevity:

- Sufficient hydrologic investigation and design.
- Use of sufficiently durable materials in construction of manmade controls.

- Proper understanding of plant communities when establishing vegetative controls and use of native species whenever possible.

- Use of stream setbacks restricting development within a specified distance of a streambank can minimize erosion and sediment loading(NCSU, 1998a).

Failure Rates: Vegetative controls may require replanting if initial plantings do not result in adequate cover. Inadequate hydraulic investigation and design or lack of maintenance may result in failure of manmade or vegetative structures.

Potential Benefits/Concerns:

Positive Impacts:

- Erosion control reduces downstream siltation, increasing downstream water quality.

- Bioengineering used alone or in concert with mechanical stabilization methods may enhance riparian habitat for wildlife (food and cover sources and temperature control for aquatic and terrestrial animals) (TBG, Inc., 1998)

- Vegetated streambanks may also enhance purification of overland runoff and provide aesthetic appeal (TBG, Inc., 1998).

Negative Impacts:

- Improperly designed stabilization measures may fail and create erosion above what might otherwise have been expected.

- Structural methods, such as rip rap, gabion baskets, etc., may be considered unsightly in some areas.

- Manmade structures cannot provide pollutant removal and absorption functions. Natural vegetation may provide some of these functions.

MISCELLANEOUS BMPs FOR URBAN CONSTRUCTION — *BMP Fact Sheet #18*

Problem

Urban construction results in areas of exposed soils, often in proximity to storm drains, streams or other water bodies. The following BMPs may be used singly or with others to reduce erosion and sedimentation.

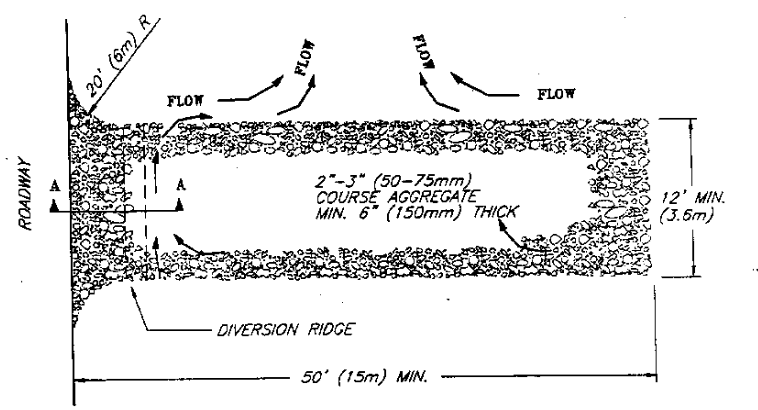
Vehicle Tracking Controls

Vehicle tracking controls stabilize construction entrances. The controls typically consist of an asphalt or rock bed at least 50 feet long separating construction areas from public roads. The asphalt or rock bed provides an area that removes loose sediment from tires of vehicles.

The asphalt or rock bed must be maintained to be effective. Maintenance includes:

- clean paved surfaces by shoveling or sweeping
- add rock to tracking pad as needed

Schematic for vehicle tracking controls



Source: Denver Regional Council of Governments, 1998

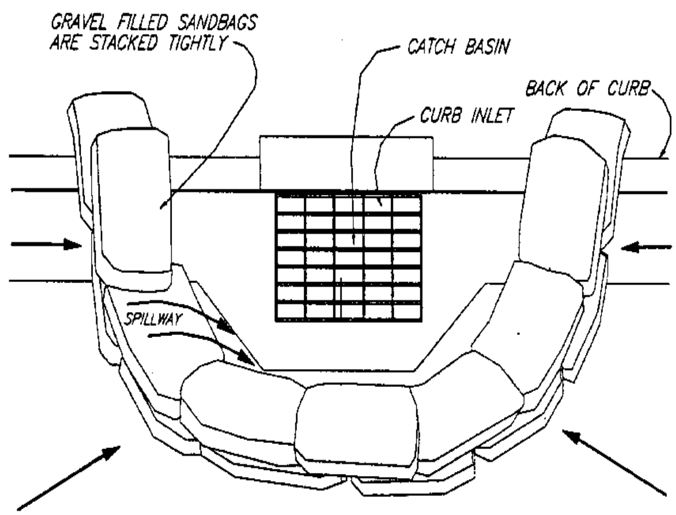
Inlet Protection

Inlet protection consists of sediment filters around storm drain drop inlets or curb inlets. Construction activities may result in significant amounts of sediments entering storm drainage system. Inlet protection should remain in place until the potential for erosion is minimal.

Gravel-filled sand bags may be packed tightly around curb inlets or drop inlets to filter sediment from storm water before it enters a storm drain system. Straw bales or filter fabric may also be used if the situation is such that they can be trenched in.

Inlet protection should not pond water so as to interfere with construction or damage adjacent property.

Schematic for Inlet Protection

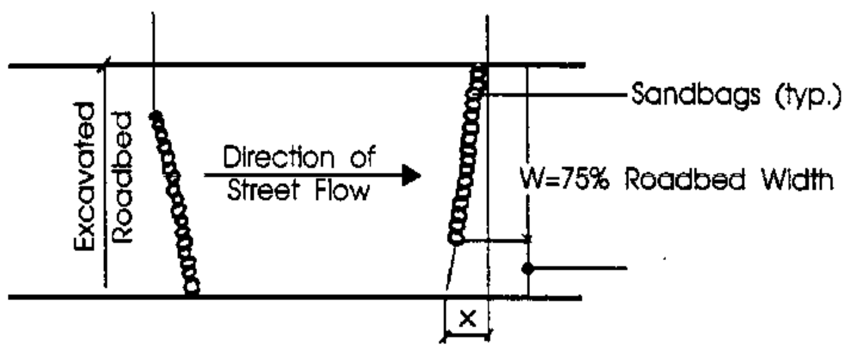


Source: Denver Regional Council of Governments, 1998

Rough-cut Street Controls

Rough-cut street controls are dirt berms or sandbag dikes used to prevent rill, channel and gully erosion on unpaved surfaces. Controls are particularly essential on streets cut onto sloping surfaces. Controls work by routing sheet flows off unpaved and unstabilized surfaces to stabilized swales along the sides of roads, other vegetated areas, or detention ponds. Controls should be installed at regular intervals along the road (especially sloping roads) and the steeper the slope, the closer the diversions should be placed. The longer a path storm water has along an unstabilized, sloping surface, the more potential there is for erosion and sediment transport off-site.

Schematic for Rough-cut street controls



Source: Denver Regional Council of Governments, 1998

Erosion Control Blankets

Erosion control blankets are used in place of mulch on areas of high velocity runoff and/or steep grade to control erosion on critical areas by protecting young vegetation.

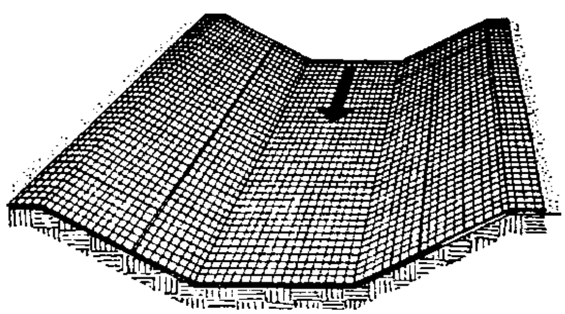
Erosion control blankets are most useful where:

- Vegetation is likely to grow too slowly to provide adequate cover
- High winds render mulch an ineffective control

As with bale check dams and silt fences, proper installation of erosion control blankets is essential for maximum erosion control.

- Erosion control blankets should be installed parallel to the direction of flow
- Blanket ends should be buried at least six inches deep
- Erosion control blankets should be placed loosely on the soil - not stretched
- Edges should be stapled at least every three feet.

Schematic for Erosion Control Blanket Installation



Source: Denver Regional Council of Governments, 1998

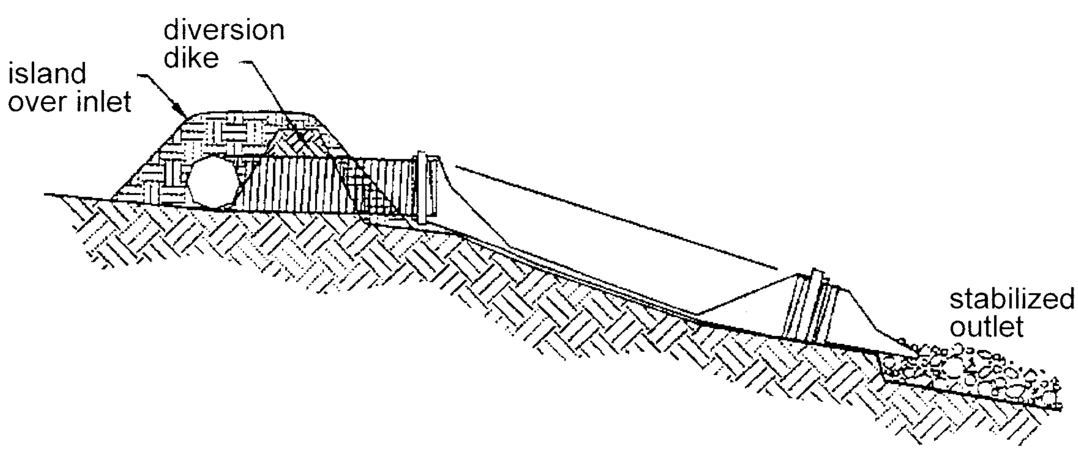
Temporary Slope Drains

Temporary slope drains are flexible or rigid conduits that extend from the top to the bottom of a cut or fill slope. Storm water is routed down the slope through the pipe to a stabilized outlet, avoiding erosion of a bare slope.

Slope drains may be permanent or temporary. Permanent slope drains are often buried, while temporary slope drains usually sit on top of the slope.

Careful installation is important; failed slope drains often result in gully erosion on the slope and sedimentation at the slope base.

Schematic for a Slope Drain



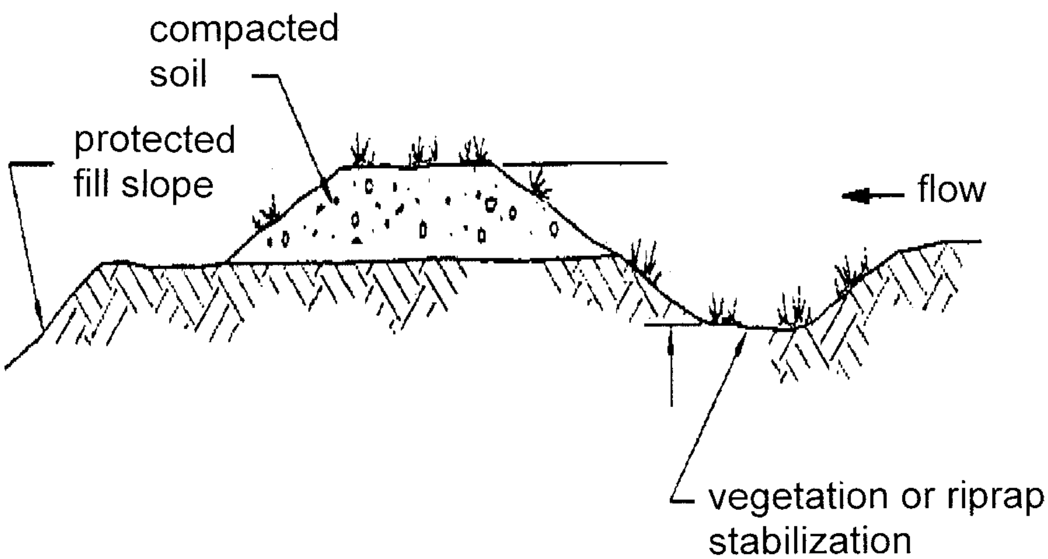
Source: Denver Regional Council of Governments, 1998

Temporary Diversion Dike

Temporary diversion dikes are, traditionally, ridges of compacted soil constructed at the top or base of a sloping disturbed area. Diversion dikes work by diverting runoff from unprotected areas or diverting sediment-laden runoff into a sediment-trapping facility.

- Vegetating the dike will further reduce sedimentation
- The gradient of the channel behind the dike should be low enough to prevent erosion, but steep enough to provide drainage
- The channel outlet should be stabilized with vegetation or rip rap.

Schematic for a Temporary Diversion Dike



Source: Denver Regional Council of Governments, 1998

Mulching and Surface Roughening

Management Options

- Rapid establishment of mulch or mulch combined with seeding can reduce runoff in cleared and graded areas by up to sixfold. Temporary stabilization within 7-14 days is recommended.

- Mulching is conducive to stabilizing sloped areas. Several materials are appropriate. The useful life is two to six months depending upon the material used. On steep slopes or in highly erodible soils, multiple treatments may be appropriate.

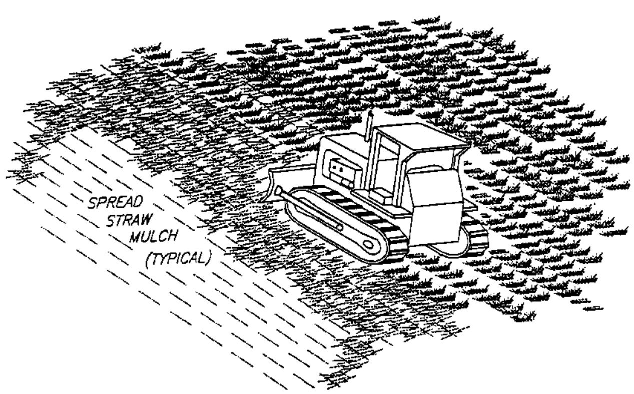
- Surface roughening involves creating grooves perpendicular to a slope. Roughening may be effective where mulching is not due to high winds or steep slopes (DRCOG, 1998). Roughening may also be the BMP of choice when activities will occur in the area within a few days.

Maintenance:

- Mulched or roughened areas should be inspected frequently, especially after rain or wind.

- Reapply mulch or surface roughening as necessary (DRCOG, 1998)

Schematics for Mulching and Surface Roughening



Source: Denver Regional Council of Governments, 1998

Construct Runoff Controls at Staging Areas

Environmental Problem

Staging areas can result in concentrations of hydrocarbons and other pollutants necessary to keep construction equipment functioning. Heavy construction traffic and construction clearing can combine to increase sediment runoff.

Management Options

Line petroleum product storage areas with impermeable barriers (clay, plastic, etc.) and create berms around them to prevent spills. Keep lids closed, tanks off the ground and all products clearly labeled.

Establish fuel and maintenance staging areas away from all drainage courses and design the areas to control runoff. Install automatic pump shut-off devices on fuel hoses to prevent spills from overfilling fuel tanks.

Plan access roads to minimize stream crossing.

Store, cover and isolate construction materials, including chemicals, to prevent runoff of pollutants and contamination of groundwater. Store only as much chemical (paints, solvents, etc.) as needed for the project. Store chemicals under cover and protected from precipitation run-on.

Develop and implement a spill control plan.

Maintain and wash equipment in confined areas to control runoff.

INDIRECT MANAGEMENT PRACTICES

DIRECT RUNOFF AWAY FROM NATURAL CHANNELS

BMP Fact Sheet #19

Environmental Problem

Runoff that directly enters a waterway may contain untreated pollutants. Urban runoff typically contains such road pollutants as hydrocarbons and metals, pesticides, fertilizers and sediments. While natural wetlands can serve a storm water treatment function, it is EPA policy that they shall not be used as a storm water treatment option to avoid potential degradation of functioning wetlands.

Management Options

Control of nonpoint sources can reduce the need for other management actions. Where possible, locate material stockpiles, borrow areas, access roads and other land disturbing activities away from critical areas such as steep slopes, highly erodible soils and areas that drain directly into sensitive water bodies.

Direct runoff into management areas or sanitary sewers that are designed to remove sediment and/or other pollutants before discharge into surface waters. Roof drains should be directed to vegetated areas rather than storm sewers whenever possible.

The **elimination of curbs and gutters** has been shown to reduce pollution entering streams and lakes. Because curbs and gutters function as channels for storm water, runoff flows at high velocities carrying sediment and other pollutants directly to surface waters. Without curbs or gutters, runoff can be spread over vegetated areas where runoff velocities can be reduced and pollutants filtered out by plants or soils. Sections of existing curb can be removed and curb outlets can be installed to flow onto well-vegetated areas. To avoid erosion, flooding and trash accumulation, the location of curb outlets should be carefully chosen and street cleaning programs should be modified to maintain these areas (NCSU, 1998).

In low-density developments curb and gutter may be replaced by grassed swales. Properly designed, swales may reduce storm water pollutants as well as convey storm water. See BMP Fact Sheet #10 for additional information.

Dry-weather flows caused by inappropriate connections to storm sewer systems can contribute significant pollutants to urban run-off. Some of the more common contributors to non-storm water flows are infiltration from leaking sanitary lines, direct connection of sanitary or industrial waste lines, failing septic systems and ground water infiltration. A program to locate and correct contaminated non-storm water flows may significantly reduce pollutants to surface waters.

PROPER DISPOSAL OF ACCUMULATED SEDIMENT

BMP Fact Sheet #20

Environmental Problem

Sediment removed form traps and basins is often disposed of in areas lacking sediment controls. Without stabilization, such as seeding, these sediments may become resuspended by storm water runoff or wind erosion.

Management Options

Placement of spoils sediment upstream of sediment traps.

Sediment spoils used as fill should not be placed within the 100 year floodplain. Fill within the floodplain increases velocities and water heights. Sediment would again be deposited into surface waters.

Land disposal should include seeding or other soils management techniques.

PROPER SNOW REMOVAL AND STORAGE

BMP Fact Sheet #21

Environmental Problem

Improper snow removal with its associated salts and roadway pollutants can damage roadside vegetation, increase chloride levels in surface and ground waters and contribute to stratification of lakes and ponds.

Management Options

Carefully site snow storage areas so that seepage and runoff does not go directly into surface or ground waters. Ideally, storage areas should have best management practices applied that serve to capture pollutants in melt water.

Snow removal management can also include management of roadway salts. Use management such as assuring proper application rates and alternatives to salts can have economic, as well as environmental benefits. Sand is an alternative that is less harmful to vegetation and aquatic life (NCSU, 1998).

Proper storage of salts in covered areas with impermeable surfaces can also reduce environmental impacts from use of road salts. This activity is regulated under the National Pollution Discharge Elimination System (NPDES) program under a general storm water permit. Installation of a secondary recovery system that collects salty runoff and reapplies it to the pile is an alternative to covering salt or sand/salt piles.

HERBICIDE/PESTICIDE/ FERTILIZER MANAGEMENT

BMP FACT SHEET #22

Environmental Problem

Frequent and/or excessive applications of herbicides, pesiticides, or fertilizers can result in pollutant loadings in surface and ground waters. Discharges to surface or ground waters typically occur due to over application, improper application or application during dormancy (useless application). Non-target plants or organism are exposed both on-site and off-site through water transportation.

Management Options

Application should be managed to achieve the greatest impact on target species. In some cases, spot verses blanket applications are as effective against target species. Spot use can significantly reduce pesticide use. Reduced application rates not only decrease the amount of chemical introduced to the environment, but may also lower the amount spent on chemical control by businesses, homeowners, construction sites and golf courses.

Xeriscaping in arid or semi-arid climates can reduce lawn maintenance, and its resulting chemical use by 50%.

Selection of less toxic, mobile and persistent chemicals with more selective pest control can be combined with a buffer area between the use site and surface waters to reduce the potential for off-site movement of chemicals.

PROTECT NATURAL AND RIPARIAN VEGETATION

BMP Fact Sheet #23

Environmental Problem

Stripping of natural vegetation can result in increased sediment loadings in surface waters. Further, in most instances, native vegetation provides better ground cover than developed plant communities.

Removal of riparian habitat and predevelopment flora and fauna results in decreased water quality. Results may include increased bank cutting, streambed scouring, siltation damage to flora and fauna, increased water temperatures, decreases in dissolved oxygen and changes to stream or river natural flow. Riparian habitat stabilizes streambanks, controlling sediments.

Management Options

In the natural state, shorelines are relatively erosion resistant. Removal of vegetation destabilizes soils resulting in soil loss and sediment loading. If vegetation must be removed, removal should be minimized. Replanting should be made with native species when possible or with other species adapted to the local climate and soils.

Avoid disturbing vegetation on steep slopes or in other critical areas.

Protect natural vegetation with fences, tree armoring, retaining walls or tree walls.

In construction areas, clear only those portions essential for completing site construction using minimum disturbance/minimum maintenance practices designed to limit clearing and grading as well as fertilizer, herbicide and pesticide use to redevelop vegetation.

Identify and preserve natural riparian buffers and systems, minimizing additional impacts. Develop community green belts where practical.

Establish riparian buffers or streambank setbacks in areas where surface water quality is dependant upon riparian areas to maintain biological integrity.

RECYCLING

Environmental Problem

Improper waste management can increase pollutant loadings in runoff to surface waters and leaching to ground waters. Improper management of household hazardous wastes typically occurs due to unawareness of proper disposal methods or lack of disposal alternatives.

Management Options

Onsite management of yard wastes by homeowners who compost lawn and yard wastes such as leaves, grass clippings and woody wastes. Many municipalities and counties offer **composting facilities** to residents at little or no charge. Composting reduces landfill volumes and the need for fertilizer by increasing soil nutrients and organic matter.

Developing a convenient, low-cost **household hazardous waste collection** program encourages proper disposal of potential pollutants. Products typically collected by these programs are used oil and antifreeze, unwanted paint and unneeded household chemicals (cleaners, pesticides, herbicides, etc.). Some jurisdictions offer free **product exchange** programs where homeowners who drop off unneeded, potentially hazardous materials may also pick up other products that may be useful to them.

Promote pollution prevention as a means of waste reduction within business and government. Pollution prevention includes recycling as a means of waste reduction, but also includes strategies to reduce use of hazardous materials such as product substitution. For many businesses recycling also cuts expenses as input materials are reused or converted to new uses within the same business or as a product for another business.

LITTER REMOVAL ***BMP Fact Sheet #25***

Environmental Problem

Litter enters surface waters via wind and runoff events. Litter and yard wastes can clog storm water control and conveyance structures making the devices ineffective in storm water pollutant control. Contaminants such as plastics and Styrofoam degrade slowly, while presenting environmental risks to fish and wildlife. Pet feces (from dogs, cats, horses, etc.) can contribute fecal coliform bacteria to surface waters. Fecal coliforms are a potential human health hazard for drinking water supplies and contact recreation, such as fishing or swimming.

Management Options

Promote litter removal programs such as Adopt-a-Highway and city/park/river clean-up days within the community. Encourage local pride within the community through civic organizations to promote individual actions affecting litter removal.

Municipal facilities maintenance programs and commercial and industrial storm water permittees should regularly clean inlets, catch basins, outlets and any other necessary areas within storm water conveyance and collection areas (NCSU, 1998).

Encourage residents to “scoop the poop” when they walk their pets. Some parks in larger cities provide bags for dog walkers. Animals, such as horses, cows, etc., should be watered away from streams, ponds or lakes to prevent direct entry of fecal material.

STREET SWEEPING — ***BMP Fact Sheet #26***

Environmental Problem

Particles accumulate along streets and in parking lots that are washed into surface waters by storm events.

Management Options

Mechanical broom sweepers are effective at removal of curbside litter and street particles greater than 400 Fm in size. Vacuum sweepers are more effective on small particles, but can not be used on wet streets. Removing smaller particles helps to reduce transport of sediment-bound pollutants (NCSU, 1998). In areas such as downtown business districts sweepers may be one of the few options for particle removal.

Disposal of street sweeping waste may pose a problem because of possible high levels of lead, zinc, copper and other wastes from automobile traffic. Testing of sweepings may be appropriate to determine disposal alternatives. Some municipalities and industries have found that street sweepings can be used as cover in sanitary landfills (NCSU, 1998).

EXPOSURE REDUCTION ***BMP Fact Sheet #27***

Environmental Problem

Runoff that directly contacts stored materials or inventory can transport pollutants to surface or ground water.

Management Options

Industries, municipalities and homeowners can reduce pollution by reducing or **eliminating exposure** by simply moving materials indoors or removing materials, products, devices and outdoor manufacturing activities that may contribute pollution to runoff. Particularly, removal of rarely used materials that are stored outdoors can be simple and effective (NCSU, 1998).

An **inventory** of the items on municipal, commercial and industrial sites that are exposed to rain may provide a useful starting point for exposure-reduction activities. Examples are raw material stockpiles, stored finished products, and machinery or engines which leak fuel or oil.

The partial or total **covering** of stockpiled or stored material. loading/unloading areas, or processing operations, waste storage areas will reduce or eliminate potential pollutants in runoff. For sites that are only partially covered directing storm water “run-on” away from materials will also reduce pollutant loading in storm water (NCSU, 1998).

Changes in **inventory management** to a “just-in-time” (JIT) method will reduce the amount of materials exposed to storm water at any given time. JIT uses precise scheduling of materials and products in and out of a site to keep the amount of raw materials and products on hand to a minimum, reducing waste, storage costs and potential pollutants exposed to storm water (NCSU, 1998).

Good housekeeping involves maintaining equipment to be free of leaks, removing empty materials containers, removing trash, sweeping of parking lots and roads, disposal of unused equipment. All these activities reduce exposure of pollutants to storm water (NCSU, 1998).

Training and prevention programs prepare employees to prevent spills and to respond quickly when spills do occur (NCSU, 1998).

EDUCATION

BMP Fact Sheet #28

Much of urban nonpoint source (NPS) pollution is the result of cumulative actions by many individuals, businesses and industries. The reduction of NPS pollution, in turn, depends the choices and actions of individuals, businesses, and industries. Often individuals and business owners are not aware that storm drains deliver runoff to nearby waterbodies without treatment. Nor are many aware that some of their common practices (over-fertilization, material storage, etc.) may contribute to pollution. Community education is one of the most effective ways of <u>preventing</u> storm water pollution.

Businesses, developers, and homeowners are all part of the NPS pollution puzzle and public awareness programs must be tailored to meet the individual needs and interests of each segment of the community. For example, programs for homeowners might focus on the use of lawn chemicals and disposal of common household wastes such as motor oil, cleaners, and herbicides. Business-oriented programs might stress good housekeeping and chemical reuse strategies. Any education program should provide not only concrete information about pollutant sources and causes, but also specific information about storing, using, and disposing of materials which may cause storm water pollution.

Involve community groups when possible. School or youth groups may be interested in stenciling storm drains with a message such as, “Dump No Waste; Drains to River.” Educational materials or presentations can be made available at a variety of community forums such as fairs, Earth Day events, town meetings, service organizations, and local festivals. “Adopt-a-River” type programs may be adapted to include educational efforts on the effects of pollution in storm water runoff.

Information on storm water best management practices and educational materials are available from many sources. Federal, state and many local governments may have written material or information on internet web pages. Many private organizations are also involved in improving urban water quality and public education. References to some of these groups may be found in the reference sections of this manual or on the internet. The Wyoming Department of Environmental Quality also has water-quality grants available annually for demonstration or assessments projects and educational programs. Depending on the source of the grants they may be awarded to state or local government units, schools, non-governmental organizations (clubs, conservation groups, *et cetera*) or individuals. Demonstration and assessment types of projects must have an educational component. For more information on grant availability and requirements contact the Nonpoint Source Program Coordinator at the Wyoming Department of Environmental Quality, Water Quality Division, 307-777-7781.

Building awareness of, not only the problems, but also the solutions to NPS pollution is critical to building public support for efforts to control pollution. Programs and ordinances will be more effective with community understanding and participation.

APPENDIX A

Additional Information

Appendix A Table 1
Advantages and Disadvantages of Management Practices

Management Practice	Advantages	Disadvantages	Comparative Cost [1]
Infiltration Basin (BMP #6, Page 39)	C Provides ground water recharge C Can serve large developments C High removal capability for particulate pollutants and moderate removal for soluble pollutants C When basin works, it can replicate predevelopment hydrology more closely than other BMP options C Basins provide more habitat value than other infiltration systems	C Possible risk of contaminating groundwater C Only feasible where soil is permeable and there is sufficient depth to rock and water table C Fairly high failure rate C If not adequately maintained, can be an eyesore, breed mosquitoes, and create undesirable odors C Regular maintenance activities cannot prevent rapid clogging of infiltration basins	Construction cost moderate but rehabilitation cost high
Infiltration Trench (BMP #5, Page 36)	C Provides ground water recharge C Can serve small drainage areas C Can fit into medians, perimeters, and other unused areas of a development site C Helps replicate predevelopment hydrology, increases dry weather baseflow, and reduces bankfull flooding frequency	C Possible risk of contaminating groundwater C Only feasible where soil is permeable and there is sufficient depth to rock and water table C Since not as visible as other BMPS, less likely to be maintained by residents C Requires significant maintenance	Cost-effective on smaller sites. Rehabilitation costs can be considerable.
Vegetative Filter Strip (BMP #11, Page 61)	C Low maintenance requirements C Can be used as parl of the runoff conveyance system to provide pretreatment C Can effectively reduce particulate pollutant levels in areas where runoff velocity is low to moderate C Provides excellent urban wildlife habitat C Economical	C Often concentrates water, which significantly reduces effectiveness C Ability to remove soluble pollutants highly vadable C Limited feasibility in highly urbanized areas where runoff velocities are high and flow is concentrated C Requires periodic repair, regrading,and sediment removal to prevent channelization	Low
Grassed Swale (BMP #10, Page 55)	C Requires minimal land area C Can be used as part of the runoff conveyance system to provide pretreatment C Can provide sufficient runoff control to replace curb and gutter in single-family residential subdivisions and on highway medians C Economical	C Low pollutant removal rates C Leaching from culverts and fertilized lawns may actually increase the presence of trace metals and nutrients	Low compared to curb and gutter

Management Practice	Advantages	Disadvantages	Comparative Cost [1]
Porus Pavement (BMP #7, Page 44)	C Provides ground water recharge C Provides water quality control without additional consumption of land C Can provide peak flow control. High removal rates for sediment, nutrients, organic matter, and trace metals C When operating properly can replicate predevelopment hydrology C Eliminates the need for storm water drainage, conveyance, and treatment systems off-site	C Requires regular maintenance C Possible risk of contaminating groundwater C Only feasible where soil is permeable, there is sufficient depth to rock and water table, and there are gentle slopes C Not suitable for areas with high traffic volume C Need extensive feasibility tests, inspections, and very high level of construction workmanship (Schueler. 1987) C High failure rate due to clogging C Not suitable to serve large-off-site areas without pretreatment	Cost-effective compared to conventional asphalt when working properly
Concrete Grid Pavement (BMP #8, Page 48)	C Can provide peak flow control C Provides ground water recharge C Provides water quality control without additional consumption of land	C Requires regular maintenance C Not suitable for area with high traffic volume C Possible risk of contaminating groundwater C Only feasible where soil is permeable, there is sufficient depth to rock and water table, and there are gentle slopes	Information not available
Filtration Basin (BMP #6, Page 39)	C Ability to accommodate medium-size development (3-80 acres) C Flexibility to provide or not provide groundwater recharge C Can provide peak volume control	C Requires pretreatment of storm water through sedimentation to prevent filter media from prematurely clogging	Information not available
Water Quality Inlet Catch Basins (BMP #16, Page 77)	C Provide high degree of removal efficiencies for larger particles and debris as pretreatment C Require minimal land area C Flexibility to retrofit existing small drainage areas and applicable to most urban areas	C Not feasible for drainage area greater than 1 acre C Marginal removal of small particles, heavy metals, and organic pollutants C Not effective as water quality control for intense storms C Minimal nutrient removal	Information not available
Water Quality Inlet Catch Basins with Sand Filter (BMPs #9, 16, Pages 51 & 77)	C Provide high removal efficiencies of particulates C Require minimal land area C Flexibility to retrofit existing small drainage areas C Higher removal of nutrients as compared to catch basins and oil/grid separator	C Not feasible for drainage areas greater than 5 acres C Only feasible for areas that are stabilized and highly impervious C Not effective as water quality control for intense storms	Information not available

Management Practice	Advantages	Disadvantages	Comparative Cost [1]
Water Qaulity Inlet/Oil-Water Seperator (BMP #16, Page 77)	C Captures coarse-grained sediments and some hydrocarbons C Requires minimal land area C Flexibility to retrofit existing small drainage areas and applicable to most urban areas C Shows some capacity to trap trash, debris, and other floatables C Can be adapted to all regions of the country	C Not feasible for drainage area greater than 1 acre C Minimal nutrient and organic matter removal C Not effective as water quality control for intense storms C Concern exists over the pollutant toxicity of trapped residuals C Require high maintenance	High, compared to trenches and sand filters
Extended Detention Dry Ponds (BMP #1, Page 16)	C Can provide peak flow control C Possible to provide good particulate removal C Can serve large development C Requires less capital cost and land area when compared to wet pond C Does not generally release warm or anoxic water downstream C Provides excellent protection for downstream channel erosion C Can create valuable wetland and meadow habitat when properly landscaped	C Removal rates for soluble pollutants are quite low C Not economical for drainage area less than 10 acres C If not adequately maintained, can be an eyesore, breed mosquitoes, and create undesirable odors	Lowest cost altemative in size range
Wet Pond (BMP #2, Page 20)	C Can provide peak flow control C Can serve large developments; most cost-effective for larger, more intensively developed sites C Enhances aesthetics and provides recreational benefits C Little ground water discharge C Permanent pool in wet ponds helps to prevent scour and resuspension of sediments C Provides moderate to high removal of both particulate and soluble urban storm water pollutants	C Not economical for drainage area less than 10 acres C Potential safety hazards if not properly maintained C If not adequately maintained, can be an eyesore, breed mosquitoes, and create undesirable odors C Requires considerable space, which limits use in densely urbanized areas with expensive land and properly values C Not suitable for hydrologic soil groups 'A' and 'B' (NRCS classification) C With possible thermal discharge and oxygen depletion. may severely impact downstream aquatic life	Moderate to high compared to conventional storm water detention

Management Practice	Advantages	Disadvantages	Comparative Cost [1]
Extended Detention Wet Pond (BMP #4, Page 29)	C Can provide peak flow control C Can serve large developments; most cost-effective for larger, more intensively developed sites C Enhances aesthetic and provide recreational benefits C Permanent pool in wet ponds helps to prevent scour and resuspension of sediments C Provides better nutrient removal when compared to wet pond	C Not economical for drainage areas less than 10 acres C Potential safety hazards if not properly maintained C If not adequately maintained, can be an eyesore, breed mosquitoes, and create undesirable odors C Requires considerable space, which limits use in densely urbanized areas with expensive land and property values C Not suitable for hydrologic soil groups 'A' and 'B'(NRCS classification) C With possible thermal discharge and oxygen depletion, may severely impact downstream aquatic life	
Constructed Storm water Wetland (BMP #3, Page 24)	C Can serve large developments; most cost-effective for larger, more intensively developed sites C Provides peak flow control C Enhances aesthetics and provides recreational benefits C The marsh fringe also protects shoreline from erosion C Permanent pool in wet ponds helps to prevent scour and resuspension of sediments C Has high pollutant removal capability	C Not economical for drainage area less than 10 acres C Potential safety hazards if not properly maintained C If not adequately maintained can be an eyesore, breed mosquitoes, and create undesirable odors C Requires considerable space, which limits use in densely urbanized areas with expensive land and property values C With possible thermal discharge and oxygen depletion, may severely impact downstream aquatic life C May contribute to nutrient loadings during die-down periods of vegetation	Marginally higher than wet ponds

Appendix A Table 2
Estimated Mean Runoff Concentrations for Land Uses, Based on the Nationwide Urban Runoff Program

(Whalen and Cullum, 1989)

Parameter	Residential	Commercial	Industrial
TKN (mg/l)	0.23	1.5	1.6
NO_3+NO_2	1.8	0.8	0.93
Total P (mg/l)	0.62	2.29	0.42
Copper (Fg/l)	56	50	32
Zinc (Fg/l)	254	418	1,063
Lead (mg/l)	293	203	115
COD (mg/l)	103	84	62
TSS (mg/l)	228	168	108
BOD (mg/l)	13	14	62

TKN (mg/l) - Total Kjeldahl nitrogen, a measure of ammonia and organic nitrogen present in a sample.

NO_3 + NO_2 - Nitrate (NO_3) plus Nitrite (NO_2), a measure of inorganic nitrogen present in a sample.

Total P - Total phosphorus in a sample.

TSS - Total Suspended Solids, a measure of the amount of suspended particles (organic and inorganic) that are small enough to remain suspended in water.

BOD - Biological Oxygen Demand, refers to the amount of oxygen that will be consumed by biological degradation of organic matter. A high BOD indicates a large amount of biodegradable organic matter that can be decomposed, primarily through microbial action. Water bodies with high BOD may lack sufficient oxygen (i.e., low dissolved oxygen, DO) to support various aquatic species.

COD - Chemical Oxygen Demand, an indirect measure of the organic content (biodegradable and non-biodegradable) of a sample. The test measures the amount of oxygen consumed by a strong oxidizing agent introduced to the sample. The higher the number, the greater the organic content. Waters with high COD often have low dissolved oxygen and impaired habitat for aquatic life.

Appendix A Table 3
Regional, Site Specific, and Maintenance Considerations for Structural Practices to Control Sediments in Storm Water Runoff

BMP Option	Size of Drainage Area	Site Requirement	Regional Restrictions	Maintenance Burdens	Longevity
Infiltration Basins (BMP #6, p. 39)	Moderate to large	Deep permeable soils	Arid & cold regions	High	Low
Infiltration Trenches (BMP #5, p. 34)	Moderate	Same as for Infiltration Basins			
Vegetated Filter Strips (BMP #11, p. 61)	Small	Low density areas with low slopes	Arid & cold regions	Low	Low if poorly maintained
Grassed Swales (BMP #10, p. 55)	Small	Low density areas with <15% slopes	Arid & cold regions	Low	High if maintained
Porus Pavement (BMP #7, p. 44)	Small	Deep permeable soils, low slopes, and restricted traffic	Arid & cold regions or high wind erosion rates	High	low
Concrete Grid Pavement (BMP #8, p. 48)	Small	Same as for Porous Pavement	Extreme freeze/thaw or high wind erosion	Moderate to high	High
Filtration Basins & Sand Filters (BMP #9, p. 51)	Widely applicable	Widely applicable	Arid & cold regions	Moderate	Low to moderate
Water Quality Inlets (BMP #16, p. 77)	Small	Impervious catchments	Few restrictions	Cleaned twice a year	High
Extended Detention Ponds (BMP #1, p. 16)	Moderate to large	Deep soils	Few restrictions	Dry ponds have relatively high burdens	High
Wet Ponds (BMP #2, p. 20)	Moderate to large	Deep soils	Arid regions	Low	High
Constructed Storm Water Wetlands (BMP #3, p. 24)	Moderate to large	Poorly drained soils, space may be limiting	Arid regions	Annual harvesting of vegetation	High

Appendix A Table 4
Effectiveness of Management Practices for Control of Runoff from Nearly Developed Areas

Management Practices		Removal Efficiency (%) TSS	TP	TN	COD	Pb	Zn	Factors
Infiltration Basin (BMP #6, p. 39)	Average:	75	65	60	65	65	65	Soil percolation rates
	Reported Range:	45-100	45-100	45-100	45-100	45-100	45-100	
	Probable Range:							
	NRCS Soil Group A	60-100	60-100	60-100	60-100	60-100	60-100	Basin surface area
	NRCS Soil Group B	50-80	50-80	50-80	50-80	50-80	50-80	
	No. Values Considered:	7	7	7	4	4	4	Storage volume
Infiltration Trench (BMP #5, p. 34)	Average:	75	60	55	65	65	65 45-	Soil percolation rates
	Reported Range:	45-100	45-100	45-100	45-100	45-100	100	
	Probable Range:							
	NRCS Soil Group A	60-100	60-100	60-100	60-100	60-100	60-100	Trench surface area
	NRCS Soil Group B	50-90	50-90	50-90	50-90	50-90	50-90	
	No. Values Considered:	9	9	9	4	4	4	Storage volume
Vegetative Filter Strip (BMP #11, p. 61)	Average:	65	40	40	40	45	60	Runoff Volume
	Reported Range:	20-80	0-95	0-70	0-80	20-90	30-90	
	Probable Range:	40-90	30-80	20-60		30-80	20-50	Slope
	No. Values Considered:	7	4	3	2	3	3	Soil infiltration rates Vegetative Cover Buffer length
Grass Swale (BMP #10, p. 55)	Average:	60	20	10	25	70	60	Runoff volume
	Reported Range:	0-100	0-100	0-40	25	3-10	50-60	
	Probable Range:	20-40	20-40	10-30		10-20	12-20	Slope
	No. Values Considered:	10	8	4	1	10	7	Soil infiltration rates Vegetative cover Swale Length Swale geometry
Porus Pavement (BMP #7, p. 44)	Average:	90	65	85	80	100	100	Percolation rates
	Reported Range:	85-95	65	80-85	80	100	100	
	Probable Range:	60-90	60-90	60-90	60-90	60-90	60-90	Storage volume
	No. Values Considered:	2	2	2	2	2	2	
Concrete Grid Pavement (BMP #8, p. 48)	Average:	90	90	90	90	90	90	Percolation rates
	Reported Range:	65-100	65-100	65-100	65-100	65-100	65-100	
	Probable Range:	60-90	60-90	60-90	60-90	60-90	60-90	
	No. Values Considered:	2	2	2	2	2	2	
Sand Filter/ Filtration Basin (BMPs #6 & 9, p. 39 & 51)	Average:	80	50	35	55	60	65	Treatment volume
	Reported Range:	60-95	0-90	20-40	45-70	30-90	50-80	
	Probable Range:	60-90	0-80	20-40	40-70	40-80	40-80	Filtration media
	No. Values Considered:	10	6	7	3	5	5	

Management Practices		Removal Efficiency (%)						Factors
		TSS	TP	TN	COD	Pb	Zn	
Water Quality Inlet (BMP #16, p. 77)	Average: Reported Range: Probable Range: No. Values Considered:	35 0-95 10-25 3	5 5-10 5-10 1	20 5-55 5-10 2	5 5-10 5-10 1	15 5-25 5-25 2	5 5-10 5-10 1	Maintenance Sedimentation storage volume
Water Quality Inlet with Sand Filter (BMP #9,16, p. 51,77)	Average: Reported Range: Probable Range: No. Values Considered:	80 75-85 70-90 1	na na 0	35 30-45 30-45 1	55 45-70 40-70 1	80 70-90 70-90 1	65 50-80 50-80 1	Sedimentation storage volume Depth of filter media
Oil/Grit Seperator (BMP #16, p. 77)	Average: Reported Range: Probable Range: No. Values Considered:	15 0-25 10-25 2	5 5-10 5-10 1	5 5-10 5-10 1	5 5-10 5-10 1	15 10-25 10-25 1	5 5-10 5-10 1	Sedimentation storage volume Oulet configurations
Extended Detention Dry Pond (BMP #1, p. 16)	Average: Reported Range: Probable Range: No. Values Considered:	45 5-90 70-90 6	25 10-55 10-60 6	30 20-60 20-60 4	20 0-40 30-40 5	50 25-65 20-60 4	20 (-40)-65 40-60 5	Storage volume Detention time Pond shape
Wet Pond (BMP #2, p. 20)	Average: Reported Range: Probable Range: No. Values Considered:	60 (-30)-91 50-90 18	45 10-85 20-90 18	35 5-85 10-90 9	40 5-90 10-90 7	75 10-95 10-95 13	60 10-95 20-95 13	Pond volume Pond shape
Extended Detention Wet Pond (BMP #2, p. 20)	Average: Reported Range: Probable Range: No. Values Considered:	80 50-100 50-95 3	65 50-80 50-90 3	55 55 10-90 1	na na 10-90 0	40 40 10-95 1	20 20 20-95 1	Pond volume Pond shape Detention time
Constructed Storm water Wetlands (BMP #3, p. 23)	Average: Reported Range: Probable Range: No. Values Considered:	65 (-20)- 100 50-90 23	25 (-125)- 100 (-5)-80 24	20 (-15)-40 0-40 8	50 20-80 2	65 30-95 30-95 10	35 (-30)-80 8	Storage volume Detention time Pool shape Wetland's biota Seasonal variation

Appendix A Table 5
A Comparative Assessment of the Effectiveness of Current Urban Best Management Practices

Urban BMP Options	Reliability for Pollutant Removal	Longevity	Applicable to Most Developments	Wildlife Habitat Potential	Environmental Concerns	Comparative Costs	Special Considerations
Storm Water Wetlands (BMP #3, p. 22)	Moderate to high, depending on design	20+ years	Applicable to most sites if land is available	High	Stream warming; natural wetland alteration	Marginally higher than wet ponds	Recommended with design improvements & the use of micro-pools & wetlands
Extended Detention Ponds (BMP #1, p. 16)	Moderate, but not always reliable	20+ years, clogging & short detention common	Widely applicable, but requires at least 10 acres of drainage area	Moderate	Possible stream warming & habitat destruction	Lowest cost alternative in size & range	Recommended with design improvements & the use of micro-pools & wetlands
Wet Ponds (BMP #2, p. 20)	Moderate to high	20+ years	Widely applicable, but requires a drainage area of greater than 2 acres	Moderate to high	Possible stream warming, trophic shifts, habitat	Moderate to high compared to conventional	Recommended with careful site evaluation
Multiple Pond Systems (BMP #4, p. 29)	Moderate to high, redundancy in-creases reliability	20+ years	Widely applicable	Moderate to high	Selection of appropriate pond option minimizes overall environmental impact	Most expensive pond option	Recommended
Infiltration Trenches (BMP #5, p. 34)	Presumed moderate	50% failure rate within 5 years	Highly restrictive (soils, groundwater, slope, areas, sediment input)	Low	Slight risk of groundwater contamination	Cost effective on smaller sites, rehab costs can be considerable	Recommended with pretreatment & geotechnical evaluation
Infiltration Basins (BMP #6, p. 39)	Presumed moderate, if working	60-100% failure rate within 5 years	Highly restrictive (see infiltration trench)	Low to moderate	Slight risk of groundwater contamination	Construction cost moderate, but rehab cost high	Not widely recommended until longevity is improved
Porus Pavement (BMP #7, p. 44)	High, if working	75% failure rate within 5 years	Highly restrictive (traffic, soils, groundwater, slope, areas, sediment input)	Low	Possible groundwater contamination	Cost effective compared to conventional asphalt when working properly	Recommended in highly restric-ted applications with careful construction & effective maintenance

Sand Filters (BMP #9, p. 51)	Moderate to high	20+ years	Applicable for smaller developments	Low	Minor	Comparatively high construction costs and frequent maintenance	Recommended with local demonstration
Grassed Swales (BMP #10, p. 55)	low to moderate, but unreliable	20+ years	Low density development & roads	Low	Minor	Low compared to curb & gutter	Recommended, with check dams as one element of a BMP system
Filter Strips (BMP #11, p. 61)	Unreliable in urban settings	Unknown, but may be limited	Restricted to low density areas	Moderate if forested	Minor	Low	Recommended as one element of a BMP system
Water Quality Inlets (BMP #16, p. 77)	Presumed low	20+ years	Small, highly impervious catchments (<2 acres)	Low	Resuspension of hydrocarbon loadings; disposal of hydrocarbon and toxic residuals	High, compared to trenches and sand filters	Not currently recommended as a primary BMP option

Appendix A Table 6
ESC Quantitative Effectiveness for Sediment Control Practices

Practice	Design Constraints or Purpose	Percent Removal of TSS	Useful Life (years)
Sediment Basin (BMP #12, p. 66)	Minimum drainage area = 5 acres, maximum drainage area = 100 acres	Average: 70% Observed range: 55%-100%	2
Sediment Trap (BMP #12, p. 66)	Maximum drainage area = 5 acres	Average: 60% Observed range: (-7%)-100%	1.5
Silt Fence (BMP #14, p. 71)	Maximun drainage area = .5 acre per 100 feet of fence. Not to be used in concentrated flow areas.	Average: 70% Observed range: 0%-100% Sand: 80%-99% Silt-Loam: 50%-80% Silt-Clay-Loam: 0%-20%	0.5
Straw Bale Barrier (BMP #14, p. 71)	Maximum drainage area = 0.25 acre per 100 feet of barrier. Not to be used in concentrated flow areas.	Average: 70% Observed range: 70%	0.25
Inlet Protection (BMP #18, p. 85)	Protect storm drain inlet.	Average: NA Observed range: NA	1
Construction Entrance (BMP #18, p. 85)	Removes sediment from vehicle wheels.	Average: NA Observed range: NA	2
Vegetative Filter Strip (BMP #11, p. 61)	Must have sheet flow.	Average: 70% Observed range: 20%-80%	2

NA = Not available
[a] Usefull life estimated as length of construction project (2 years)
[b] Trap volume = 1800 cf/ac (.5 inches run-off per acre)

Appendix A Table 7
Pollutant Concentrations in Highway Runoff

Pollutant	Event Mean Concentration for Highways with Fewer than 30,000 Vehicles per day (mg/L)	Event Mean Concentration for Highways with More than 30,000 Vehicles per day (mg/L)
Total Suspended Solids*	41	142
Volatile Suspended Solids	12	39
Total Organic Carbon	8	25
Chemical Oxygen Demand*	49	114
Nitrite and Nitrate*	0.46	0.76
Total Kjeldahl Nitrogen*	0.87	1.83
Phosphate Phosphorus	0.16	0.40
Copper (Cu)	0.022	0.054
Lead (Pb)	0.080	0.400
Zinc (Zn)	0.080	0.329

Event Mean Concentrations are for the 50% median site.

*These terms are defined in Appendix A, Table 2.

Volatile Suspended Solids (VSS) - That portion of Total Suspended Solids that contain carbon and are combustible. VSSs may originate from incompletely combusted vehicle exhaust particulates or the products of tire wear.

Total Organic Carbon (TOC) - The total amount of organically bound carbon in a sample. Materials such as fuels, oils, and pesticides contain organically bound carbon.

Phosphate Phosphorus - The amount of phosphorus present as phosphate (PO_4) in a sample.

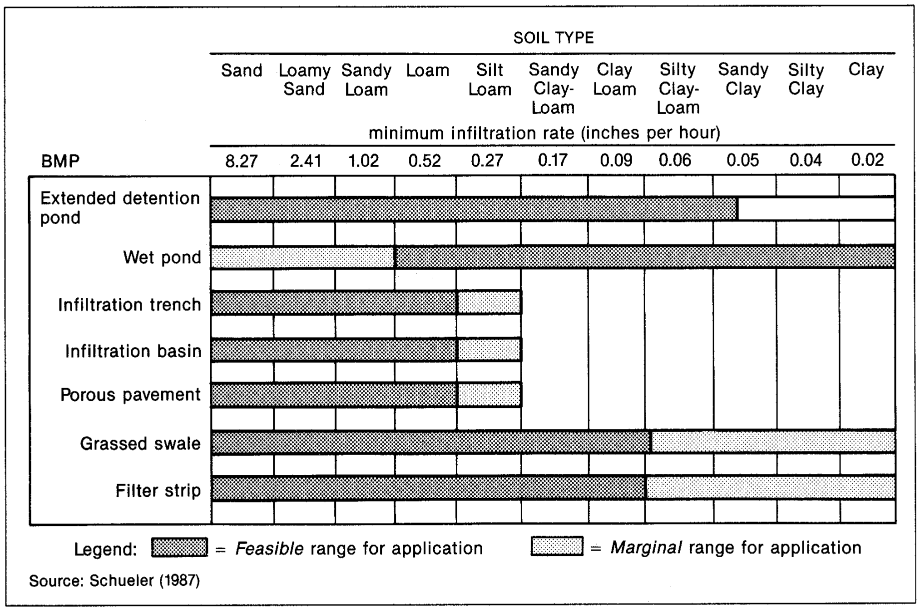
Appendix A Table 8
Effectiveness and Cost Summary for Roads, Highway and Bridges
Operation and Maintenance Management Practices

Management Practice	% Removal						Cost
	TSS	TP	TN	COD	Pb	Zn	
Maintain Vegetation							
For Sediment Control							Natural succession allowed to occur -
Average	90	NA	NA	NA	NA	NA	Average: $100 per acre per year
Reported Range	50-100	NA	NA	NA	NA	NA	Reported Range: $50-$200/ac/year
Probable Range	80-100	-	-	-	-	-	
For Pollution Removal							Natural succession not allowed to occur -
Average	60	40	40	50	50	50	Average: $800 per acre per year
Reported Range	0-100	0-100	0-70	20-80	0-100	50-60	Reported Range: $700-$900/ac/year
Probable Range	0-100	0-100	0-100	0-100	0-100	0-100	
Pesticide/Herbicide Use Management							Generally accepted as an economical program to control excessive use.
Average	NA						
Reported Range	NA						
Probable Range							
Street Sweeping							Average: $20 per curb mile
Smooth Street, Frequent Cleaning							Reported Range: $10-$30 per curb mile
(One or more passes per week)							
Average	20	NA	NA	5	25	NA	
Reported Range	20	NA	NA	0-10	5-35	NA	
Probable Range	20-50	-	-	0-10	20-50	10-30	
Infrequent Cleaning							
(One pass per month or less)							
Average	NA	NA	NA	NA	5	NA	
Reported Range	NA	NA	NA	NA	0-10	NA	
Probable Range	0-20	-	-	-	0-20	0-10	
Litter Control							Generally accepted as an economical approach to control excessive use.
Average	NA						
Reported Range	NA						
Probable Range							

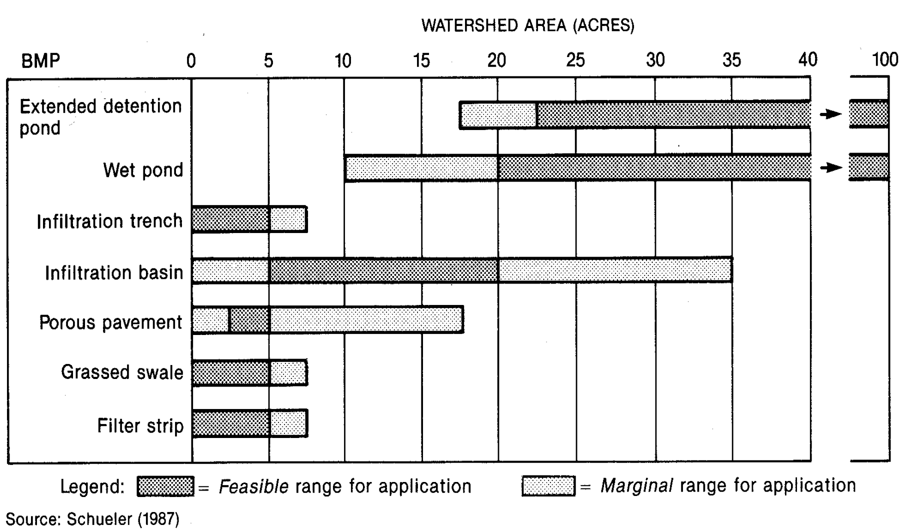
Management Practice	% Removal						Cost
	TSS	TP	TN	COD	Pb	Zn	
General Maintenance (e.g. pothole and roadside repairs)							Generally accepted as an economical preventative maintenance program by local and State agencies.
Average	NA						
Reported Range	NA						
Probable Range							
Protection of Salt Piles							For salt storage building -
Average	NA						Average: $30 per ton salt
Reported Range	NA						Reported range: $10-$70 /ton salt
Probable Range	90-100 [a]						
Minimization of Application of Deicing Salts							Generally accepted as an economical preventative maintenance program by local and State agencies.
Average	NA						
Reported Range	NA						
Probable Range							
Specially Equipped Salt Application Trucks							For spread rate control on truck -
Average	NA						Average: $6,000 per truck
Reported Range	NA						Reported range: $6,000 per truck
Probable Range							
Use of Alternative Deicing Materials							CMA -
Average	NA						Average: $650 per ton
Reported Range	NA						Reported range: $650 per ton
Probable Range							(note: cost of salt $30/ton)
Contain Pollutants Generated During Bridge Maintenance							Varies with method of containment use.
Average	NA						
Reported Range	NA						
Probable Range	50-100 [b]						

NA = Not Applicable
[a] Measured as a reduction in salt
[b] Measured as a reduction in all pollutants

Appendix A Figure 1
Restrictions for BMP Application Based on Soil Permeability



Appendix A Figure 2
Feasible BMPs for Different Watershed Sizes



GLOSSARY

ADSORPTION - Adhesion of the molecules of a gas, liquid or dissolved substance to a surface. Adsorption differs from absorption in that absorption is the assimilation **or** incorporation of a gas, liquid or dissolved substance into another substance.

ADJUSTABLE GATE VALVE - A knife gate valve, activated by a handwheel, used to control the internal diameter of reverse slope pipes or allow rapid opening of the pond drain pipe.

AGGREGATE - Term for the stone or rock gravel needed to fill in an infiltration BMP such as a trench or porous pavement. Clean-washed aggregate is simply aggregate that has been washed clean so that no sediment is associated with.

AQUATIC BENCH - A ten to fifteen foot bench around the inside perimeter of a permanent pool that is approximately one foot deep. Normally vegetated with emergent plants, the bench augments pollutant removal, provides habitat, conceals trash and water level drops, and enhances safety.

ARTIFICIAL MARSH CREATION - Simulation of natural wetland features and functions via topographic and hydraulic modifications on non-wetland landscapes. Typical objectives for artificial marsh creation include ecosystem replacement or storm water management.

BMP FINGERPRINTING - Term refers to a series of techniques for locating BMPs (particularly ponds) within a development site so as to minimize their impacts to wetlands, forest and sensitive stream reaches.

BACTERIAL DECOMPOSITION OR MICROBIAL DECOMPOSITION - Microorganisms, or bacteria, have the ability to degrade organic compounds as food resources and to absorb nutrients and metals into their tissues to support growth.

BANK RUN - Gravelly deposits consisting of smooth round stones, generally indicative of the existence of a prehistoric sea. Such deposits are normally found in coastal plain regions.

BANK STABILIZATION - Methods of securing the structural integrity of earthen stream channel banks with structural supports to prevent bank slumping and undercutting of riparian trees, and overall erosion prevention. To maintain the ecological integrity of the system, recommended techniques include the use of willow stakes, imbricated riprap or brush bundles.

BANKFULL DISCHARGE - A flow condition where streamflow completely fills the stream channel up to the top of the bank. In undisturbed watersheds, the discharge condition occurs on average every one and a half to two years and controls the shape and form of natural channels.

BASEFLOW - The portion of stream flow that is not due to storm runoff, and is supported by groundwater seepage into a channel.

BERM, EARTHEN - An earthen mound used to direct the flow of runoff around **or** through a BMP.

BEST MANAGEMENT PRACTICE (BMP) - Structural devices that temporarily store or treat urban storm water runoff to reduce flooding, remove pollutants, and provide other amenities.

BIOFILTRATION - The use of a series of vegetated swales to provide filtering treatment for storm water as it is conveyed through the channel. The swales can be grassed, or contain emergent wetlands, or high marsh plants.

BIOLOGICAL MONITORING - Periodic surveys of aquatic biota as an indicator of the general health of a waterbody. Biological monitoring surveys can span the trophic spectrum, from macro-invertebrates to fish species.

CATCHMENT - See **CONTRIBUTING WATERSHED AREA.**

CHANNEL EROSION - The widening, deepening, and headward cutting of small channels and waterways, due to erosion caused by moderate to larger floods.

CHECK DAM - (a) A log or gabion structure placed perpendicular to a stream to enhance aquatic habitat. (b) An earthen or log structure, used in grass swales to reduce water velocities, promote sediment deposition, and enhance infiltration.

CONTRIBUTING WATERSHED AREA - Portion of the watershed contributing its runoff to the BMP in question.

DELTA-t - The magnitude of change in the temperature of downstream waters.

DESIGN STORM - A rainfall event of specified size and return frequency (e.g., a storm that occurs only once every 2 years) that is used to calculate the runoff volume and peak discharge rate to a BMP.

DE-WATERING - Refers to a process used in detention/retention facilities, whereby water is completely discharged or drawn down to a preestablished pool elevation by way of a perforated pipe. De-watering allows the facility to recover its design storage capacity in a relatively short time after a storm event.

DOWNSTREAM SCOUR - Downstream channel erosion usually associated with an upstream structure that has altered hydraulic conditions in the channel.

DROP STRUCTURE - Placement of logs with a weir notch across a stream channel. Water flowing through the weir creates a plunge pool downstream of the structure and creates fish habitat.

DRAWDOWN - The gradual reduction in water level in a pond BMP due to the combined effect of infiltration and evaporation.

DRY POND CONVERSION - A modification made to an existing dry storm water management pond to increase pollutant removal efficiencies. For example, the modification may involve a decrease in orifice size to create extended detention times, or the alteration of the riser to create a permanent pool and/or shallow marsh system.

EXTENDED DETENTION (ED) PONDS - A conventional ED pond temporarily detains a portion of storm water runoff for up to twenty-four hours after a storm using a fixed orifice. Such extended detention allows urban pollutants to settle out. The ED ponds are normally "dry" between storm events and do not have any permanent standing water.

An enhanced ED pond is designed to prevent clogging and re-suspension. It provides greater flexibility in achieving target detention times. It may be equipped with plunge pools near the inlet, a micro pool at the outlet, and utilize an adjustable reverse-sloped pipe at the ED control device.

ED CONTROL DEVICE - A pipe or series of pipes that extend from the riser of a storm water pond that are used to gradually release storm water from the pond over a 12 to 48 hour interval.

EMBANKMENT - A bank (of earth or riprap) used to keep back water.

EMERGENT PLANT - An aquatic plant that is rooted in the sediment but whose leaves are at or above the water surface. Such wetland plants provide habitat for wildlife and waterfowl in addition to removing urban pollutants.

END OF PIPE CONTROL - Water quality control technologies suited for the control of existing urban storm water at the point of storm sewer discharge to a stream. Due to typical space constraints, these technologies are usually designed to provide water quality control rather than quantity control.

EXFILTRATION - The downward movement of runoff through the bottom of an infiltration BMP into the subsoil.

EXTENDED DETENTION - A storm water design feature that provides for the gradual release of a volume of water (0.25 - 1.0 inches per impervious acre) over a 12 to 48 interval times to increase settling of urban pollutants,. and protect channel from frequent flooding.

FILTER FABRIC - Textile of relatively small mesh or pore size that is used to (a) allow water to pass through while keeping sediment out (permeable), or (b) prevent both runoff and sediment form passing through (impermeable).

FLOW SPLITTER - An engineered, hydraulic structure designed to divert a portion of stream flow to a BMP. located out of the channel, or to direct storm water to a parallel pipe system, or to bypass a portion of baseflow around a pond.

FOREBAY - An extra storage area provided near an inlet of a BMP to trap incoming sediments before they accumulate in a pond BMP-

FREQUENT FLOODING - A phenomenon in urban streams whereby the number of bankfull and sub-bankfull flood events increases sharply after development. The frequency of these disruptive floods is a direct function of watershed imperviousness.

FRINGE WETLAND CREATION - Planting of emergent aquatic vegetation along the perimeter of open water to enhance pollutant uptake, increase forage and cover for wildlife and aquatic species, and improve the appearance of a pond.

GABION - A large rectangular box of heavy gauge wire mesh which holds large cobbles and boulders. Used in streams and ponds to change flow patterns, stabilize banks, or prevent erosion.

GEOMEMBRANE - Lining of filter fabric on the bottom and sides of porous pavement to prevent lateral or upward movement of soil into the stone reservoir.

GEOTEXTILE FABRIC - See **FILTER FABRIC-**

GRASSED SWALE - A conventional grass swale is an earthen conveyance system in which the filtering action of grass and soil infiltration are utilized to remove pollutants from urban storm water. An enhanced grass swale, or biofilter, utilizes checkdams and wide depressions to increase runoff storage and promote greater settling of pollutants.

GRAVITATIONAL SETTLING - The tendency of particulate matter to "drop out" of storm water runoff as it flows downstream when runoff velocities are moderate and/or slopes are not too steep.

HEAD - Pressure.

HIGH MARSH - Diverse wetland type found in areas that are infrequently inundated or have wet soils. In pond systems, the high marsh zone extends form the permanent pool to the maximum ED water surface elevation.

INFILTRATION BASIN - An impoundment where incoming storm water runoff is stored until it gradually exfiltrates through the soil of the basin floor.

INFILTRATION TRENCH - A conventional infiltration trench is a shallow, excavated trench that has been backfilled with stone to create an underground reservoir. Storm water runoff diverted into the trench gradually exfiltrates from the bottom of the trench into the subsoil and eventually into the water table.

An enhanced infiltration trench has an extensive pretreatment system to remove sediment and oil. It requires an on-site geotechnical investigation to determine appropriate design and location.

LEVEL SPREADER - A device used to spread out storm water runoff uniformly over the ground surface as sheet flow (i.e., not through channels). The purpose of level spreaders are to prevent concentrated, erosive flows from occurring, and to enhance infiltration.

LOW MARSH - Wetland type with emergent plant species that require some depth of standing water throughout the year. The low marsh zone in pond systems is created in areas where the permanent pool is zero to twelve inches deep.

LOWFLOW CHANNEL - An incised or paved channel from inlet to outlet in a dry basin which is designed to carry low runoff flows and/or baseflow, directly to the outlet without detention.

mg/l - Milligrams per liter

MPN/L - Most probable number per liter. A statistical method to estimate numbers of bacterial colonies in a water sample. Often used to estimate fecal coliform contamination.

MICRO POOL - A smaller permanent pool used in a storm water pond due to extenuating circumstances, i.e. concern over the thermal impacts of larger ponds, impacts on existing wetlands, or lack of topographic relief.

MICROTOPOGRAPHY - Refers to the contours along the bottom of a shallow marsh system. A complex micro topography creates a great variety of environmental conditions that favor the unique requirements of many different species of wetland plants.

MULTIPLE POND SYSTEM - A collective term for a cluster of pond designs that incorporate redundant runoff treatment techniques within a single pond or series of ponds. These pond designs employ a combination of two or more of the following: extended detention, permanent pool shallow wetlands, or infiltration. Examples of a multiple pond system include the wet ED pond, ED wetlands, infilter ponds and pond-marsh systems.

NATURAL BUFFER - A low sloping area of maintained grassy or woody vegetation located between a pollutant source and a waterbody. A natural buffer is formed when a designated portion of a developed piece of land is left unaltered from its natural state during development. A natural vegetative buffer differs from a vegetated filter strip in that it is "natural" and in that they need not be used solely for water quality purposes.

To be effective, such areas must be protected against concentrated flow.

OBSERVATION WELL - A test well installed in an infiltration trench to monitor draining times after installation.

OFF-LINE BMP - A water quality facility designed to treat a portion of storm water (usually 0.5 to 1.0 inches per impervious acre) which has been diverted from a stream or storm drain.

OFF-LINE TREATMENT - A BMP system that is located outside of the stream channel or drainage path. A flow splitter is used to divert runoff from the channel and into the BUT for subsequent treatment.

OIL/GRIT SEPARATOR - A best management practice consisting of a three-stage underground retention system designed to remove heavy particulates and absorbed hydrocarbons. Also known as a **WATER QUALITY INLET.**

OUTFALL - The point of discharge for a river, drain, pipe, etc.

PARALLEL PIPE SYSTEM - A technique for protecting sensitive streams. Excess storm water runoff is piped in a parallel direction along the stream buffer instead of being discharged directly into the stream.

PEAT SAND FILTER - Best management practice, utilizing the natural adsorptive features of fabric or hemic peat, which consists of a vertical filter system with a grass cover crop, alternating layers of peat and sand and a sediment forebay feature. The peat sand filter is presently used for municipal waste treatment systems and is being adapted for use in storm water management.

PERMANENT POOL - A three to ten foot meter deep pool in a storm water pond system, that provides removal of urban pollutants through settling and biological uptake. (Also referred to as a wet pond).

PHRAGMITES (***Phragmites australis***) **-** A tall bamboo-like grass frequently found along streams and other wet areas.

PHYSICAL FILTRATION - As they pass across or through a surface, particulates are separated from runoff by grass, leaves and other organic matter on the surface.

PILOT CHANNEL - A riprap or paved channel that routes runoff through a BMP to prevent erosion of the surface.

PLUNGE POOL - A small permanent pool located at either the inlet to a BMP or at the outfall form a BMP. The primary purpose of the pool is to dissipate the velocity of storm water runoff, but it also can provide some pretreatment, as well.

PONDSCAPING - A method of designing the plant structure of a storm water wetland or pond using inundation zones. The proposed wetland or pond system is divided into zones which differ in the level and frequency of inflow. For each zone, plant species are chosen based on their potential to thrive, given the inflow pattern of the zone.

POROUS PAVEMENT - An alternative to conventional pavement whereby runoff is diverted through a porous asphalt layer and into an underground stone reservoir. The stored runoff then gradually infiltrates into the subsoil.

RETROFIT - The creation/modification of storm water management systems in developed areas through the construction of wet ponds, infiltration systems, wetland plantings, stream bank stabilization, and other BMP techniques for improving water quality and creating aquatic habitat. A retrofit can consist of the construction of a new BMP in the developed area, the enhancement of an older storm water management structure, or a combination of improvement and new construction.

REVERSE SLOPE PIPE - A pipe that extends downwards from the riser into the permanent pool that sets the water surface elevation of pool. The lower end of the pipe is located up to 1 foot below the water surface. Very useful technique for regulating ED times, and it seldom clogs.

RIPARIAN - A relatively narrow strip of land that borders a stream or river, often coincides with the maximum water surface elevation of the one-hundred year storm.

RIPARIAN REFORESTATION - The replanting of the banks and floodplain of a stream with native forest and shrub species to stabilize erodible soils, improve both surface and ground water quality, increase stream shading, and enhance wildlife habitat.

RIPRAP - A combination of large stone, cobbles and boulders used to line channels, stabilize banks, reduce runoff velocities, or filter out sediment..

RISER - A vertical pipe extending from the bottom of a pond BMP that is used to control the discharge rate from a BMP for a specified design storm.

ROTOTILLING - Mechanical means of tilling, or rotating, the soil.

RUNOFF CONVEYANCE - Methods for safely conveying storm water to a BMP to minimize disruption of the stream network, and promote infiltration or filtering of the runoff.

RUNOFF FREQUENCY SPECTRUM - The frequency distribution of unit area runoff volumes generated by a long, term continuous time-series of rainfall events. Used to develop BMP and storm water sizing rules.

RUNOFF PRETREATMENT - Techniques to capture or trap coarse sediments before they enter a BMP to preserve storage volumes or prevent clogging within the BMP. Examples include forebays and micropools for pond BMPS, and plunge pools, grass filter strips and filter fabric for infiltration BMPS.

SAFETY BENCH - A ten to fifteen foot bench located just outside the perimeter of a permanent pool. The bench extend around the entire shoreline to provide for maintenance access and eliminate hazards.

SAND FILTER - A relatively new technique for treating storm water, whereby the first flush of runoff is diverted into a self-contained bed of sand. The runoff is then strained through the sand, collected in underground pipes and returned back to the stream or channel.

An enhanced sand filter utilizes layers of peat, limestone, and/or topsoil, and may also have a grass cover crop. The adsorptive media of an enhanced sand filter is expected to improve removal rates.

SEDIMENT FOREBAY - Storm water design feature that employs the use of a small settling basin to settle out incoming sediments before they are delivered to a storm water BMP.. Particularly useful in tandem with infiltration devices, wet ponds or marshes.

SHORT CIRCUITING - The passage of runoff through a BMP in less than the theoretical or design treatment time.

SLURRY - Thin mixture of water and any of several fine, insoluble materials; therefore, an OIL SLURRY is a thin mixture of water and oil.

STORM WATER TREATMENT - Detention, retention, altering or infiltration of a given volume of storm water to remove urban pollutants and reduce frequent flooding.

STORM WATER WETLAND - A conventional storm water wetland is a shallow pool that creates growing conditions suitable for the growth of marsh plants. A storm water wetland is designed to maximize pollutant removal through wetland uptake, retention and settling.

A storm water wetland is a constructed system and typically is not located within delineated a natural wetland. In addition, a storm water wetland differs from an artificial wetland created to comply with mitigation requirements in that the storm water wetland does not replicate all the ecological functions of natural wetlands.

An enhanced storm water wetland is designed for more effective pollutant removal and species diversity. It also includes design elements such as a forebay, complex micro topography, and pondscaping with multiple species of wetland trees, shrubs and plants.

STREAM BUFFER - A variable width strip of vegetated land adjacent to a stream that is preserved from development activity to protect water quality, aquatic and terrestrial habitats.

SUBSOIL - The bed or stratum of earth lying below the surface soil.

SUBSTRATE AMENDMENTS - A technique to improve the texture, and organic content of soils in a newly excavated pond system. The addition of organic rich soils is often required to ensure the survival of aquatic and terrestrial landscaping around ponds.

SUMP PIT - A single-chamber oil/grit separator used to pretreat runoff before it enters an infiltration trench.

SWALE - A natural depression or wide shallow ditch used to temporarily store route, or filter runoff.

TRASH AND DEBRIS REMOVAL - Mechanical removal of debris, snags, and trash deposits from the streambanks to improve the appearance of the stream.

um/l or Fm/l - Microgram per liter.

UNDERDRAIN - Plastic pipes with holes drilled through the top, installed on the bottom of an infiltration BMP, or sand filter, which are used to collect and remove excess runoff.

VACUUM SWEEPING - Method of removing quantities of coarse-grained sediments from porous pavement in order to prevent clogging. Not effective in removing finegrained pollutants.

VEGETATED FILTER STRIP - A vegetated section of land designed to accept runoff as overland sheet flow from upstream development. It may adopt any natural vegetated form, from grassy meadow to small forest. The dense vegetative cover facilitates pollutant removal.

A filter strip cannot treat high velocity flows; therefore, they have generally been recommended for use in agriculture and low density development.

A vegetated filter strip differs from a natural buffer in that the strip is not "natural"; rather, it is designed and constructed specifically for the purpose of pollutant removal. A filter strip can also be an enhanced natural buffer, however, whereby the removal capability of the natural buffer is improved through engineering and maintenance activities such as land grading or the installation of a level spreader.

A filter strip also differs from a grassed swale in that a swale is a concave vegetated conveyance system, whereas a filter strip has a fairly level surface.

WATER QUALITY INLET - Best management practice consisting of a three-stage underground retention system designed to remove heavy particulates and absorbed hydrocarbons. Also, known as an **OIL/GRIT SEPARATOR or a WATER/OIL SEPARATOR.**

WATERSHED INCH - A storm event that produces enough precipitation to cover the area of a watershed one inch deep.

WEIR - A structure that extends across the width of a channel and is intended to impound, delay or in some way alter the flow of water through the channel. A **CHECK DAM** is a type of weir as is any kind of dam.

A **PORTED WEIR** is a wall or dam that contains openings through which water may pass. Ported weirs slow the velocity of flow and therefore, can assist in the removal of pollutants in runoff by providing opportunities for pollutants to settle, infiltrate or be adsorbed.

WET POND - A conventional wet pond has a permanent pool of water for treating incoming storm water runoff.

In enhanced wet pond designs, a forebay is installed to trap incoming sediments where they can be easily removed; a fringe wetland is also established around the perimeter of the pond.

WETLAND MITIGATION - Regulatory requirement to replace wetland areas destroyed or impacted by proposed land disturbances with artificially created Wetland areas.

WETLAND MULCH - A technique for establishing low or high marsh areas where the top twelve inches of wetland soil form a donor wetland are spread thinly over the surface of a created wetland site as a mulch. The seedbank and organic matter of the mulch helps to rapidly establish a diverse wetland system.

WETLAND PLANT UPTAKE - Wetland plant species rely on nutrients (i.e., phosphorus and nitrogen) as a food source; thus, they may intercept and remove nutrients from either surface or subsurface flow.

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